

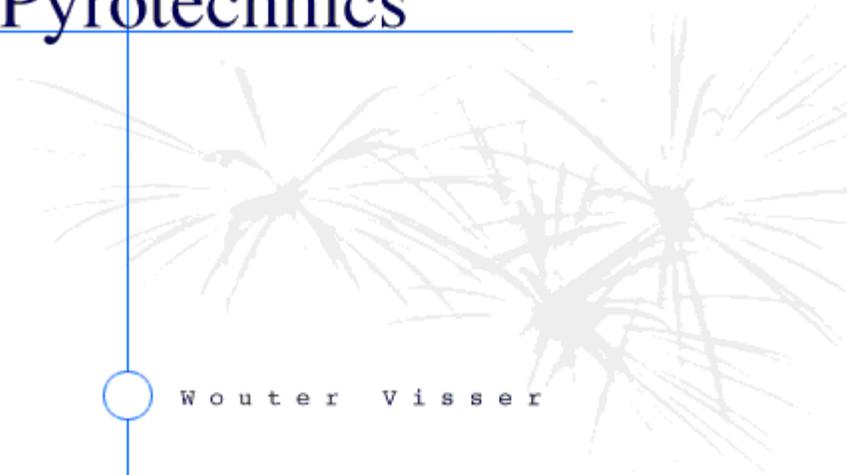
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Nov 2003

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Practical

Pyrotechnics



W o u t e r V i s s e r

About

A little bit about this page..

Disclaimer

Read the disclaimer. Leave this page if you do not agree with it.

Getting started

Things you absolutely need to know to get started. [Finding more info](#), [Acquiring materials](#), [basic safety](#), [mixing techniques](#) and more.

Chemicals

A description of several chemicals used in pyrotechnics and instructions on how to make or where to buy them. Special attention has been paid to the preparation of [chlorates and perchlorates](#).

Tools

The tools of the trade, including instructions for building a ball mill and press.

Formulae

A collection of over 300 pyrotechnic compositions, modern and ancient, provided as a reference only.

Device components

Instructions on making some basic components of pyrotechnic devices, such as fuse, stars, tubes, and black powder.

Finished devices

Instructions on making some actual fireworks, such as rockets, shells, fountains and starmines.

Links

Links to a number of my favourite pyrotechnics related websites.



stay green

Preface

This page is about pyrotechnics, or actually just a subsection of the field of pyrotechnics: fireworks. Fireworks have been enjoyed by people in many cultures for many centuries. Most countries have one or several days on which fireworks are traditionally used for celebrations. Examples are New years eve (Netherlands, Germany), 14 July (France), independence day (US) and Guy Fawkes day (UK). There seems to be something about fireworks that is liked by almost everyone. It is hard to say what exactly that is. It is many things. Some people, like me, are fascinated by the composition and construction of fireworks. Fireworks are an interesting blend of science, tradition and art.



ROGER BACON
"When the flame of powder toucheth
the soul of man it burneth exceeding deep"

One of the purposes of this page is to make pyrotechnics as a hobby more accepted and liked. Another reason is to shift some people's interests from making only loud bangs to more interesting and effectfull pyrotechnics. Furthermore, I hope that this page can provide beginners in pyrotechnics a safe start by providing some practical information. I required quite some time finding the information I needed and hope to save other people some time. Finally, there are some sections on miscellaneous pyrotechnics related subjects I found interesting.

Experimenting with fireworks

In the Netherlands experimenting with fireworks is considered really stupid. You should expect funny looks if you mention that pyrotechnics is your hobby. Laws are very strict. Fireworks may only legally be fired a couple of hours a year (on new years eve), and only be owned and bought 3 days a year.

The organisation SIRE has been concerned with decreasing the number of fireworks related injuries in the Netherlands in the past few years, with great success. Their commercials are very well known, as they were often quite shocking (showing injured and amputated limbs of fireworks victims) while others were quite funny. Even though the campaign has proven quite effective in general (the number of injuries has been steadily decreasing for several years now) I do feel that it is ineffective for certain groups of people in particular. The majority of victims consists of what the internet pyro community refers to as 'kewl bomb dudes'. Every year, plenty of people in the Netherlands disassemble commercial fireworks to construct incredibly dangerous devices with the thus obtained pyrotechnic mixtures. There is another way.

With the right knowledge and by experimenting carefully on a small scale I believe it is possible to experiment with fireworks in a responsible manner. Working with pyrotechnic materials is inherently dangerous, but taking the right precautions and handling the various compositions in the right way can reduce the risk to acceptable levels (at least to my standards ;). In the Netherlands, this kind of experimenting is illegal, and I certainly advice against doing anything against the law. However, history teaches us that there will always be a (relatively small) number of people that will experiment away regardless of law or advice. With only the best of intentions, out of simple deep rooted interest and fascination with pyrotechnics but nevertheless, illegally. It is my conviction that it is best to educate these people properly and reduce the risk of accidents in that way.

This brings us to the main reason this page exists: to provide practical information to those that cannot resist the temptation to experiment with fireworks. The focus lies with safety, knowledge and building some more beautiful and interesting fireworks than a mere loud BANG. Lastly, I hope fireworks as a hobby will be more accepted in general.

Continuously under construction

This page is (still) not complete and probably never will be. I do try to work on it from time to time (occasionally with long interposes). So, please do come back some time and you may find something new.

All email is welcome at: wvisser@dds.nl



Note: If I do not answer email immediately, please remind me.

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Also note that although I have tried to comment on the most obvious safety aspects of the described procedures, I may have forgotten things and have been inconsistent. Keep that in mind at all times. Use your common sense, and use more than one reliable source of information before doing anything. Feel free to contact me or someone else if you have any questions whatsoever!

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I can be reached at: wvisser@dds.nl

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Getting started

Getting started in pyrotechnics can be hard. It took me several years to simply obtain the materials I needed and learn how to do things properly. This page may help you on your way. It discusses the most important basic information you will need as well as info on acquiring chemicals, tools and information.

Pyrotechnics as hobby

Fireworks as a hobby can be very rewarding. Great, professional quality, fireworks can be made by an amateur with little equipment. However, it can also be extremely dangerous if insufficient attention is paid to the safety aspects of working with pyrotechnic materials. Because of this it is illegal to make fireworks yourself in most countries.

As an aspiring 'pyro', it is absolutely essential that you spend as much time as possible learning about the properties of pyrotechnic mixtures, the ways to properly prepare and handle them and the techniques used to construct fireworks with them. This must be learned well even way before you consider mixing up your first batch of composition.

Literature

As with most things, the best way to get started is to read as much about the subject as you can, and there are several sources you can turn to. Some interesting information can be found on the internet, and there are some very good paper-and-ink books too. Things that can help you on your way can be found on [this](#) page.

Obtaining chemicals and tools

The first problem that you will probably encounter is obtaining the [chemicals](#) you need. And besides chemicals, there are [tools](#) that are needed or are at least very handy to have. Luckily, a lot of things can be made or bought.

Mixing

One of the first things you will have to learn is how to mix chemicals safely into compositions. This can never be done with complete safety. By their nature, pyrotechnic compositions are powerful, potentially dangerous mixtures. It is therefore of the utmost importance that you always employ proper [mixing techniques](#). That will minimise the risk of accidental ignition during mixing. The books mentioned in the literature section discuss this topic as well.

Compressing composition

Another technique that is almost essential is that of [compressing compositions](#) into their casings. This process can generate lots of shocks and friction that can potentially ignite a composition. Therefore, some special attention must be paid to the details of this technique.

General safety

Pyrotechnic compositions and devices can never be handled with absolute safety. However, the risk can be reduced to an acceptable level (at least to my standards) by using proper methods and materials. Exactly what methods and materials are best used differ per situation. Different mixtures must be handled differently, and construction techniques vary between people. There is not always a clear 'right' or 'wrong' method. However, some [general safety guidelines](#) can be given that make working with pyrotechnic materials safer. In general, an increased knowledge about pyrotechnics will increase your safety as well since you will be more capable of assessing risks and preventing accidents.

Some simple projects

Once you have read those books, and obtained the tools and chemicals, you have arrived at the point where you have both the materials and knowledge to build some interesting pieces of fireworks. The construction of a number of standard pyrotechnic [devices](#) are described on this page.

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Finding reliable information

There are few schools that teach pyrotechnics. In past centuries techniques and compositions were kept secret and passed from parents to children in family businesses. Today, information is spread more freely, although particularly interesting or difficult effects are often still kept secret. There are however many books on pyrotechnics, and some good information has recently become available on the internet as well (though there is at least as much dangerous garbage too).

Books

If you are seriously thinking about doing anything with pyrotechnics, you cannot do without at least one good book. At least one, but the more the better. You should buy at least one book on pyrotechnics in general and if necessary a simple chemistry book. You don't need much chemistry but you should master the basics. Most bookstores don't have books on pyrotechnics in store, but the somewhat larger, better stocked ones will usually be happy to order them for you. On the web a couple of pages can be found with companies where these books can be ordered and a list of suggestions can be found [here](#).

Info on the internet

Like mentioned above there is some good info available, but there is also a lot of dangerous info. It can be hard to tell the difference, so obviously the internet is not the best place to get your information. (in this hobby, being informed well can make the difference between life and death). A short, incomplete list of interesting sites can be found [here](#). Again, it -will- give you an idea of this hobby, you -can- learn a lot from the internet, but it **-will not-** always provide reliable info. If you search the net you will sooner or later encounter 'the big book of misschief', or the 'anarchists cookbook' or the 'jolly roger cookbook'. These deal mostly with high explosives and building bombs, grenades, mines, etc. at home. These things have NOTHING to do with fireworks. Spectacular they may be, but also dangerous and intended to harm or kill. Obviously, fireworks are not. Additionally, about all the instructions given in these books are incomplete, incorrect and generally dangerous.

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General safety

Important note: It is impossible to give a finite set of rules that will assure your safety in pyrotechnics. Described below you will find just some of the most important and common ('everyday') things that should always be kept in mind when handling pyrotechnic compositions and chemicals. They apply to a wide variety of compositions. **But** every composition is different. Some must be rammed or pressed to work properly. Other will explode when rammed. Some must be wet with water, others may spontaneously ignite when wet. Some mixtures are relatively safe to use by themselves but are extremely sensitive when used together. (A number of well known 'incompatible' mixtures and chemicals are also listed below). The point is: remember and think about the rules below, they are important, but realise any such list is inevitably incomplete. Accidents happen even in places where every conceivable safety precaution is taken. I don't guarantee your safety if you follow the rules below (also read the [disclaimer](#)), but merely say it is wise to do so. It'll increase your safety.

General Safety Precautions

With that said, a list of some generally useful safety precautions in no particular order:

1. Never smoke when handling chemicals or compositions.
2. Be sure you are familiar with all the properties of the compositions you work with. Thoroughly test new compositions for sensitivity, stability, compatibility with other mixtures etc, until you are absolutely sure that the mixture is ok to use in your application and method of construction. Find out as much as you can about other peoples experiences with a particular mixture.
3. Use only non-sparking tools. Make your tools from either: wood, paper, aluminum, lead or brass. Other metals and materials may spark (especially steel will).
4. Paper bags or wooden containers are good to use for storing mixed compositions. Store compositions dry and cool. Avoid plastics, glass and metal. Avoid storing compositions in general. Make as much as you will need in the near future and keep no more in stock than necessary.
5. Never have large amounts of composition near you. If you must use larger amounts of composition in multiple items, store the bulk of composition in a safe place and bring only small amounts to your working place. Finished items should also be brought to a safe place immediately.
6. Prevent contamination of chemicals and mixtures. Have separate tools for every type of mixture (i.e. blackpowder-like mixtures, chlorates, perchlorates, etc) and clean them well with hot water and/or alcohol after use. It is no luxury either to have different sets of clothing for working with different mixtures. Wash them every time after use (dust collects in the clothing). If you have the possibility, have separate rooms or better yet: separate buildings for working with different types of mixtures/chemicals.
7. Related to 6: Keep a clean working place. Fine dust easily spreads all over your working place. Keep chemicals in closed cabinets or in a separate building. Mixtures should not be kept in the working place anyway (see rules 4 and 5).
8. Provide adequate ventilation. This is especially important when working with volatile solvents or (poisonous, flammable) powdered chemicals. Not only can you get yourself poisoned, vapour or dust may also ignite.
9. Be aware of static electricity buildup. Ground your working table. Monitor humidity and keep it above 60% as a rule of thumb. This can be especially important in winter when preparing for new years eve (on the Northern Hemisphere at least). Touch a grounded surface before you place things on it. Touch other people before handing over compositions or finished items. Wear cotton clothing, avoid synthetics (do not be tempted to wear fleece clothing if your working place is cold in winter). Simple things such as unscrewing a (plastic) bottle, unwinding some tape or even moving your arm may accumulate enough charge on your body to ignite a sensitive composition. The risk of static electricity is often underestimated or even completely ignored by beginning amateurs in pyro, while it is actually one of the major causes of accidents in both commercial/industrial and amateur pyro setups.
10. Wear proper protective clothing. A face shield, dust mask, heavy gloves and a leather apron are minimal. Wear cotton clothing. Hearing protection can be good but it also makes it harder to hear other people's warnings.
11. Provide safety screens between you and compositions, especially when pressing, ramming, sieving or in other

ways causing frictions/shocks/pressure etc.

12. Be prepared for the worst. Have a plan for when something should go wrong. Have a fire extinguisher and plenty of water ready. Think beforehand of what might happen and how you could minimize the damage. Know how to treat burns. Inform someone else so he/she can help in case of an accident. Have a fast escape route from your working place.
13. Test a device well before showing it to an audience. Inform any audience well of what can happen.

'Incompatibilities'

Some combinations of chemicals lead to especially sensitive or instable mixtures. There are many more of such incompatible chemicals/mixtures than listed here but these are some of the more commonly encountered types:

1. **Chlorates and sulfur.** Mixtures containing both are not only very sensitive to friction and shock but are also known to ignite spontaneously. The sulfur reacts with water and air to form trace amounts of sulfuric acid. This will react with chlorates to form chlorine dioxide, a yellow explosive gas that will ignite most flammable materials upon contact. Addition of small amounts of barium or strontium carbonate to chlorate based compositions is sometimes done to prevent buildup of acid, even in compositions without sulfur. Many older texts on pyrotechnics describe the use of chlorate/sulfur based compositions. Today, many alternative and much safer compositions are available and there is therefore no excuse for the use of chlorate/sulfur mixtures. This also means chlorate based compositions cannot be used in items that also contain sulfur based mixtures. For example: chlorate based stars cannot be primed with black powder. Nor can a H3 burst charge be used with black powder primed stars (or stars containing sulfur).
2. **Chlorates and ammonium compounds.** Mixing these will allow ammonium chlorate to form in a double decomposition reaction that takes place in solution (moisture speeds up the process). Ammonium chlorate is a highly instable explosive compound. It decomposes over time producing chlorine dioxide gas (see chlorates and sulfur). Mixtures are likely to spontaneously ignite upon storage or may explode for no apparent reason. An exception seems to be the use of ammonium chloride and potassium chlorate in some smoke compositions. According to Shimizu this combination is safe due to the lower solubility of potassium chlorate (compared to ammonium chlorate). I personally would still use these mixtures with great caution (or avoid them) since it seems inevitable that small amounts of ammonium chlorate will still form. The lower solubility of potassium chlorate will make it the -main- product in a double decomposition reaction but not the -only- product.
3. **Chlorates with metals and nitrates.** These mixtures show the same problems as chlorate/ammonium compound mixtures. The reason is that nitrates can be reduced by most metals used in pyrotechnics to ammonium. The reaction rate of this reaction is increased by presence of water. Over time (for example when drying) these mixtures may spontaneously ignite or become extremely sensitive. The fact that ammonium forms in a relatively slow reaction is treacherous. These mixtures are referred to as 'death mixes' by some.
4. **Aluminum and nitrates.** Mixtures of these compounds sometimes spontaneously ignite, especially when moist. The mechanism is assumed to be as follows: the aluminum reduces some of the nitrate to ammonium, simultaneously forming hydroxyl ions. The aluminum then reacts with the alkaline products in a very exothermic reaction leading to spontaneous heating up of the mixture. This can eventually lead to ignition. The reactions take place in solution and therefore moisture speeds up the reaction. The process is usually accompanied by the smell of ammonia. Some types of aluminum are more problematic than others. Stearin coated aluminum is generally safer to use. The whole process can be prevented in many cases by the addition of 1 to 2 percent of boric acid. This will neutralise the alkaline products. It is best to bind such compositions with non-aquaeous binder/solvent systems such as red gum/ethanol. Since aluminum/nitrate mixtures are extensively used it is important to be aware of this problem which is why the combination is listed here.

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Mixing techniques

Mixing of pyrotechnic ingredients is a basic skill that every pyro must master. Mixing pyrotechnic compositions is not as simple as it may seem at a first glance and improper mixing techniques are a common cause of accidents among beginning amateur pyro's. Depending on the sensitivity and required properties of the mixture different mixing techniques may be employed. Below you'll find three descriptions of accepted methods with which most mixtures can be made.

[Diapering method](#)

[Screening method](#)

[Ball milling method](#)

Diapering method

The diapering method can be used for a wide variety of mixtures of all sensitivities. It produces very little friction and is used for mixtures as sensitive as flash as well as for less sensitive mixtures such as most fountain compositions. Up to a pound of composition may be conveniently mixed at a time (although this is strongly discouraged for powerfull and sensitive mixtures such as flash).

1. Prior to mixing, sieve the chemicals to remove clumps. Sieve each chemical separately. Break any clumps up, sieve again, and repeat this until all passes the sieve.
2. Take a large sheet of (not too thin) paper and spread it out on a flat surface.
3. Place the chemicals in the center of the paper
4. Pick up two opposite corners of the paper and alternately lift them so that the chemicals roll together.
5. Before the composition tends to fall off the paper, place the sheet back on the working surface and pick up the two other corners. Repeat the previous step with these corners.
6. Repeat as often as necessary to obtain a homogenous mixture.

Screening method

This method produces more friction than the diapering method. It is therefore unsuitable for sensitive mixtures such as flash. It is advised to use this method only for relatively insensitive mixtures such as black-powder like mixtures. Metal containing mixtures are best mixed with the diapering method as metal particles may spark with the sieve. Main advantage of the screening method is that it is fast and much less laborous than the diapering method.

1. Take a sieve with a coarse grid. It is much preferable to use a brass sieve since it will not spark.
2. Place the chemicals together in a (wooden or glass) bowl and mix them roughly with a wooden spoon.
3. Skoop the mixture on the sieve and sieve it onto a paper sheet
4. When all has passed, transfer the mixture to the bowl again and repeat the sieving as often as necessary to obtain a homogenous mixture. Small clumps that won't pass through the sieve may be broken up by applying gentle pressure with the back of a wooden spoon or a piece of paper.

Ball Milling method

Mixing with the ball milling method produces a lot of friction, shocks and maybe static electricity and is therefore dangerous. It can only be used with very insensitive mixtures and even then it must done with utmost caution and proper safety precautions. The only reason it is used (besides that is very simple and not labour intensive) is that it will produce superior mixtures: extremely homogenous and well mixed. For making lift-grade quality black powder a ball

mill seems essential. I would advise that only mixtures of potassium nitrate, charcoal and sulfur be mixed with the ball milling method. Other mixtures are usually more sensitive. Ofcourse most pure chemicals can safely be ground with the ball mill. Also see the notes on the pages dealing with [making black powder](#) and the [ball mill](#).

1. Take a ball mill
2. Insert the chemicals, wet them with an appropriate solvent
3. Turn it on and let it run for the required time to obtain a homogenous mixture.

That's basically all there is to the mixing itself. Safely operating a ball mill is a subject on it's own and is not described here. Read the linked pages above for some comments on that.

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Chemicals

Chemicals can be either bought or made. There are several places where usefull chemicals can be bought. There are dedicated pyro chemicals suppliers, such as [Skylighter](#), but several chemicals can also be bought at supermarkets, hardware stores, etc.

Some chemicals are easily made at home, others take a little more effort. For me it has almost become a hobby in itself to prepare the chemicals I need. Listed below you'll find a number of chemicals that may be of use. The names are linked to information on the chemicals, ways to make them and/or places they can be bought other than at a pyro supplier. Some basic chemistry knowledge is assumed, which can be found in any good general chemistry book if you are not familiar with the described methods or reactions. Some preparations will require the use of toxic or dangerous chemicals. Be sure you know and use the proper safety precautions when experimenting and dispose of toxic or dangerous chemicals properly.

[Acetone](#)

Antimony trisulfide

Alloprene, see Parlon

[Aluminum](#)

[Ammonium chloride](#)

[Ammonium nitrate](#)

[Ammonium perchlorate](#)

[Barium carbonate](#)

[Barium chlorate](#)

[Barium nitrate](#)

Barium peroxyde

[Barium sulfate](#)

Bentonite, see clay

[Boric acid](#)

[Calcium sulfate](#)

[Charcoal](#)

[Clay](#)

[Colophonium](#)

[Copper acetoarsenite](#)

[Copper benzoate](#)

[Copper chromite](#)

Copper(I)chloride

[Copper\(II\)oxyde](#)

[Dextrine](#)

[Ethanol](#)

[Iron](#)

[Iron oxide \(red\)](#)

Kaolin, see clay

[Lead tetraoxide](#)

[Manganese dioxide](#)

[Magnalium](#)

[Magnesium](#)

[Methanol](#)

[Nitric acid](#)

[Nitrocellulose](#)

[Parlon](#)

Paris green, see Copper acetoarsenite

Pergut, see Parlon

[Potassium benzoate](#)

[Potassium chlorate](#)

[Potassium dichromate](#)

[Potassium nitrate](#)

[Potassium perchlorate](#)

[Polyvinyl chloride \(PVC\)](#)

[Red gum](#)

[Saran](#)

[Shellac](#)

[Sodium benzoate](#)

[Sodium chlorate](#)

[Sodium nitrate](#)

[Sodium perchlorate](#)

Sodium salicylate

[Strontium carbonate](#)

[Strontium nitrate](#)

[Strontium sulfate](#)

[Sulfur](#)

[Sulfuric acid](#)

[Titanium](#)

[Zinc](#)

[Zinc oxide](#)

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Chlorate and Perchlorate Manufacturing

at a Small Scale

Introduction

Chlorates and perchlorates are among the most often used oxidisers in pyrotechnics. Especially potassium perchlorate, KClO_4 , potassium chlorate KClO_3 , ammonium perchlorate, NH_4ClO_4 , and barium chlorate BaClO_3 are used extensively. Chlorates and perchlorates are chemically related but from a pyrotechnical standpoint perchlorates are generally safer to use. Chlorates require special handling. Mixtures made with tend to be more sensitive than similar mixtures based on perchlorates and some may ignite spontaneously. Potassium chlorate is extensively used commercially since it is cheaper than potassium perchlorate, and many accidents have happened that might have been prevented if the corresponding perchlorate was used instead. The use of chlorates is therefore not recommended. If you do decide to use them, make sure you really understand what you are getting involved with.

The amateur pyrotechnist can prepare chlorates and perchlorates at home with some effort. Homemade chemicals are usually more expensive than commercially produced chemicals and it is ofcourse laborous, but taking shipping costs into account, the fact that perchlorates and chlorates are sometimes quite hard to obtain in most countries and their usefulness in pyrotechnics it may pay to try to make your own. Chlorates are the easiest to prepare, but again, the use of chlorates is not recommended for amateur use.

Index

The information is split up in three sections, one on chlorates, one on perchlorates, and one of analysing the products of your efforts. The most commonly used method to prepare both chlorates and perchlorates is the electrochemical method, which is described best in the text on chlorate synthesis. The text on perchlorate synthesis often refers to it.

- [Preparing chlorates](#)
- [Preparing perchlorates](#)
- [Analysis of products](#)

Credits

The information on these pages is a selection of the experiences, results and ideas of a group of people interested in chlorate and perchlorate synthesis. If not for them, these pages would not exist. Therefore, many thanks go to Rich Weaver, Mike Brown, Lee Clock, Johan Grundlingh, Rande Pete, James Carle, E.S., Jim Selin and a few others that prefer not to have their names listed here.

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Tools

Scale: Your most important tool will be an accurate scale, which you can find in most cooking supply stores. Try to find one that is accurate to 1 g at least.

M&P: Another thing you will probably need is a mortar and pestle. This can usually be found in cooking supply stores as well.

Star pump: To make pressed or pumped stars, a [star pump](#) is needed. Instructions on making a very simple but usable star pump are given.

Press: Pressing is safer and more consistent than ramming. A simple [press](#) may be build from easily available materials.

Ball Mill: Another usefull tool is a [ball mill](#). It is used to grind chemicals to a very fine powder. It can also be used in some cases to mix powder, but be sure you know what you are doing when you attemp that. A ball mill is essential for making good quality black powder at home.

Rocket tooling: For making rockets some special [rocket tooling](#) is required. You'll need spindles, sleeves and rammers.

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Device components

Many pyrotechnic devices are constructed using the same things. For example, fuse and cardboard are used in practically any device. On this page you will find links to instructions on making a number of such generally usefull things.

[Black powder](#), the oldest and most essential mixture in pyrotechnics. It is used for all sorts of things. Fuse, burst charge, propellant, priming, lift charges, etc. etc. It pays to spend some time trying to make a good quality of black powder. Having good black powder makes the construction of a lot of things easier.

[Fuse](#), indispensable, ofcourse. For providing a delay, for connecting things together etc. Fuse exists in many varieties with different properties. Commercial fuse is usually more reliable than homemade fuse, but for some purposes the reduced reliability is not really a problem.

[Paper tubes](#) are commonly used for casings. It is an ideal material for this purpose: strong, yet easy to work with, sufficiently resistant to fire, sparkless, and it will not produce dangerous shrapnell in the event of an explosion. Tubes can be found in many places. They can also be bought, and ofcourse, you can roll your own. A technique that takes some practice to do well, but can be very usefull.

[Stars](#) produce the majority of the effect of many items. Shells, starmines, roman candles, etc. They consist of clumps of pyrotechnic composition held together by binders. Since so many devices depend on stars for their effects, mastering the art of making good stars can greatly improve the quality of your fireworks.

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Pyrotechnic devices

Instructions on making a number of basic pyrotechnic devices are listed below. They are listed in order of increased complexity, so when just starting in pyrotechnics it is probably best to start at the top and work your way down. The number and variety of devices is currently a bit limited, and if I can find the time I hope to expand it in the near future.

[Lances](#) consist of a paper tube filled with composition. They burn away slowly, emitting light. Different colors may be produced depending on the composition used. Lances are often used to produce letters and figures. For that purpose a number of them are attached to a frame and ignited simultaneously.

[Fountains](#) come in all sizes, ranging from tiny fountains with a 2 cm flame for use on birthday cakes to fountains such as 'Clark's giant steel fountain', which reaches a height of many meters. The effect usually consists of a spray of sparks of different types and colors. Exploding microstars are sometimes employed as well.

[Rockets](#) are among the most fascinating pyrotechnic devices man has ever invented. Some people spend all their time on just perfecting and building rockets. The Chinese are usually credited with inventing the rocket. Today's technology has made use of the exact same basic principle to propel spacecraft all over the solar system. This page cannot possibly cover the entire field of rocketry adequately. Instructions on building small rockets for propelling fireworks up into the sky are given. The motors are of the same ancient design used by the Chinese centuries ago.

[Buzz bombs](#) are only a small step away if you have mastered the technique of making rockets. In fact, they may be easier to make since they do not require the amount of thrust rockets do to work. Buzz bombs are items that when ignited spin around very quickly, thereby making a characteristic buzzing sound. They bounce around on the ground, or a propeller may be attached to them to lift them up into the air for several meters. This is one of my personal favourites.

[Starmines](#) produce a short but magnificent effect by launching a cloud of stars up into the sky in a single burst. An unconventional but working method of making these has been described here. To make starmines, the art of making [stars](#) has to be learned first.

[Shells](#) usually constitute the major part of professional fireworks displays. Shells, again, come in a variety of sizes, types and effects. Many people enjoy making shells as they are one of the most impressive fireworks items and the range of attainable effects is virtually unlimited. In most countries they are only sold to professionals since the amount of pyrotechnic composition is quite large and they require special handling. A simple, small shell of a traditional Italian design is described in the instructions.

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Links

Just some of my personal favourites in no particular order.

Private pages

- [Dan Williams'](#) impressive homepage is an absolute must-see site on amateur pyrotechnics, featuring illustrated detailed instructions on making some very high quality tooling and fireworks items.
- [Tom Dimock's page](#) features the internet's largest number of well maintained, up-to-date pyro related links.
- [Richard Nakka's](#) Experimental Rocketry Site is an amazing site on both theory and practice of rocketry.
- [Tom Smith's](#) page has among other things an extensive glossary of pyro terms.
- [Paul Marriot's](#) page, featuring The Benson and Hedges International Fireworks Competition.
- [The PFP](#), by Andrew Krywonizka. A great page featuring an enormous formula database.
- [Philistophony](#), a great page about the chemistry and physics of pyrotechnics.
- [Fireworks Island](#), a varied site with pictures, quizzes, video, magazines and much more.
- [Pyro panel](#) by Ken Groulay
- [Backyard Ballistics](#) is an interesting site on rocketry.
- [Lindsay Greene's](#) site is an interesting site on amateur pyro.
- [DJ's page](#) features instructions on making an amazing -nozzleless- BP rocket, as well as a blue strobe rocket.

Clubs and organisations

- [The Pyrotechnics Guild International](#)
- [The National Council on Fireworks Safety](#)
- [Western Pyrotechnic Association](#)
- [Western New York Pyrotechnic Association's](#) homepage has some practical information for the amateur pyro as well.
- [Connecticut Pyrotechnic Association](#)

Publishers and suppliers

- [Skylighter](#), Quality pyrotechnic chemicals and other supplies. They have a catalog online and will ship some products worldwide.
- [FireFox Enterprises](#) also is a dedicated pyro supplier, mainly orientated at the US market.
- [Thunder & Lightning Tool, Inc.](#) also sell a great variety of quality tools, they have an illustrated online catalog and make custom tools.
- [The Journal of Pyrotechnics](#) Inc. publishes a wealth of interesting reading material for both advanced and beginning pyro's.
- [American Fireworks News \(AFN\)](#) also publishes lots of of usefull material for amateur pyro's.

Display companies, manufacturers and retailers

- [Wizard devices](#)
- [Kimbolton Fireworks](#) a British company owned by the famous rev. R. Lancaster, author of "Fireworks, principles and practice"
- [Grucci](#), a well known family business, located in New York, USA
- [Skyscenes](#) specializes in operator fired displays, DIY kits and indoor- and theatrical effects.

So far this (incomplete) list. Do you miss your page listed here, or know of any other interesting pages? Please let me know. (wfvissier@dds.nl)

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Compressing compositions

Quite often a powder needs to be formed into a solid mass to control the burn rate, for example in the construction of fountains, rockets and lances. Depending on the composition used and the application, different methods may be used to accomplish this. Ramming and pressing are the most commonly used methods. Due to the shocks, friction and enormous forces involved in these processes, they can be dangerous. Mixtures may ignite when rammed or pressed and it is therefore of the utmost importance that the techniques for doing this as safe as possible are learned. Another commonly used method is to hold a composition together with a binder. The binder of choice depends on the particular composition. This too can be dangerous if an improper binder or solvent is used. Below, each method is described.

[Ramming](#)

[Pressing](#)

[Binding](#)

Ramming

This method is used to fill tubes with composition. Small amounts of powdered composition are added to the tube, a dowel is inserted and the powder is compacted with a hammer. Obviously, this method can only be used for very insensitive compositions. Mixtures consisting of nitrates, charcoal and sulfur are commonly rammed. Many rocket propellants and fountain compositions are made with just these three chemicals. However, metal powders are often added to these mixtures for spark effects and this makes them more sensitive. Although these mixtures are also commonly rammed, it is good to know about their increased sensitivity. Mixtures containing chlorates or perchlorates should never be rammed. They are much more sensitive than nitrate based mixtures. Such mixtures are pressed or bound instead.

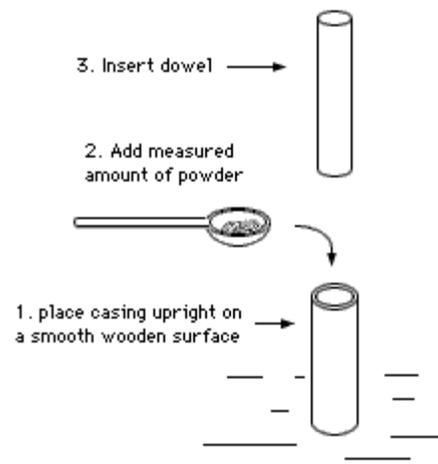
From comparing accounts of accidental ignitions during ramming, it seems that the most likely thing to happen is that the dowel will be blown out of the casing, sometimes with force, and the composition will then steadily burn away. If you are wearing proper protective clothing (eye and ear protection, face shield, heavy gloves and heavy (eg leather) apron are minimal), followed the safety tips in the [safety](#) section and did not lean over the casing while ramming, the risk of serious injury is minimal.

Perchlorate and chlorate based mixtures are not only more sensitive, they also burn at a greater rate. In case of accidental ignition these mixtures are more likely to cause an explosion instead of a relatively harmless steady combustion. Protective clothing will provide little protection against explosions, and this is another reason why perchlorate and chlorate based mixtures should never be rammed.

1) Place the casing to be filled on a smooth wooden surface. Sometimes, when the casing is relatively thin, a 'sleeve' is used to prevent it from splitting. For more information on this, check out the [rocket tools](#) and [rocket construction](#) pages.

2) Add a small amount of loose composition to the casing. Use no more composition than will give a layer as thick as the casings inner diameter after ramming, or the casing may wrinkle. Also, the powder may not be fully compacted. This often results in inconsistent performance and explosions.

3) Tap the casing to settle the powder, and insert the dowel. The dowel should slide easily into and out of the casing, yet there should be little clearance between dowel and casing. As a rule of thumb, use a dowel 1 mm smaller than the inner diameter of the casing if the casings inner diameter is less than 20

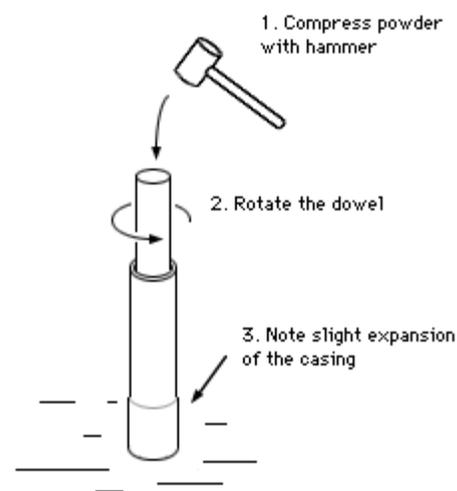


mm. If larger casings are used, use a dowel 2 or 3 mm smaller than the casing.

4) Push the dowel down firmly using your hands. This will compact the powder a bit and allow most of the air trapped between the grains to escape.

5) Now, using a wooden or rubber-coated hammer, give the dowel a few blows. Everyone seems to have his or her own method, but in any case it is important to be consistent: use the same number of blows everytime, and try to use about the same amount of force. My method is to give three intermediately strong blows, lift the dowel slightly, rotate it a third of the way, give another three blows, lift, rotate and ram once more and then repeat, this time using stronger blows.

6) When the casing is filled to the required level, remove the sleeve if used and inspect the casing. It should not be wrinkled, and a slight expansion of the casing is usually a good sign. A very tight sleeve may prevent the casing from expanding however, even if enough force was applied.



Pressing

Pressing produces less shocks and friction than ramming, reducing the risk of accidental ignition. It also allows the operator to be at a distance from the composition, and a blast screen can be mounted in between. Therefore, pressing is a much safer method of compression than ramming. More sensitive compositions can be used, increasing the range of effects achievable. Compositions that are unsensitive enough to be rammed may be pressed instead, possibly increasing safety. So, even though you can do without, after some time you will probably want to construct a [press](#). A simple solution for small items is to use a large vice for pressing, as is described on the press page.

1) If necessary, insert the casing in a sleeve.

2) Add a small, measured amount of composition. Like before, use no more than will give a layer as thick as the inner diameter of the casing to prevent wrinkling and incomplete compression.

3) Insert the dowel. As explained in the ramming section, it should slide easily in and out of the casing but fit the casing well. Insert the casing in the press.

4) Now, position yourself behind the blast screen. Hopefully needless to say, a blast screen is no excuse for not wearing protective clothing. In case of accidental ignition an explosion is very likely since the press provides extra confinement. While the dowel was free to move out of the casing in ramming and allow a way of escape for the gasses generated, during pressing it is not. So, as always, wear at least heavy gloves, face shield and a leather apron.

5) Now, compress the powder. Try to exert about the same amount of force everytime, to improve consistency. Some people use a pressure gauge to actually measure the force. Others simply try to judge the force they are exerting themselves on the press. If the performance of your items is inconsistent, reconsider your technique of pressing first. In general it seems best to apply as much force as possible without splitting the casing.

6) Wait for a few seconds, then release the pressure.

7) Remove the casing from the press, and repeat steps 2 through 6 until the casing is filled to the required level.

8) Inspect the casing. It should not have wrinkled, and slight expansion is usually a good sign. A very tight sleeve may prevent the casing from expanding however, even if enough force was applied.

Binding

This method relies on a different principle than the other two. A binder is added to the powdered composition, some solvent is added, the dough is shaped as required and allowed to dry. This method has many applications, probably more than it is commonly used in. In the past few decades, polymerising binding agents have found increasing application as well. These do not need to be dissolved in a solvent and can therefore be used to manufacture large solid masses of composition in non-porous casings. These binders find widespread use in rocket propellant manufacturing, but I've heard of people using the same technique to produce stars and lances.

This method produces very little friction and may be used with comparatively sensitive compositions. However, the use of solvent can cause some other difficulties. The binder/solvent system used must be compatible with the composition. For some more details, read the 'incompatibilities' section on the [safety](#) page.

1) Prepare the composition. Following the instructions, add the binder as a dry powder to the composition or dissolve it in a solvent. If a curing (polymerising) binder is used, add the monomere.

2) If the binder was added as a powder to the composition, spray the composition with a solvent. If the binder was dissolved, wet the composition with the required amount of solvent. In general, the first method is better since this allows control over the amount of binder used. Indications for the use of solvent are generally quite vague (along the lines of 'make the composition into a wet paste', or 'a stiff dough'). This page is not different in that respect, and this is where some experience comes in. As a rule of thumb however, it is best to add as little solvent as possible. Add small amounts of solvent, mix them well into the composition, and stop when the right consistency has been achieved. If a polymerising binder is used, the exact amount should be stated since it usually constitutes a significant part of the composition. To start the polymerising process, different methods are employed depending on the polymere. We will assume that the process is started by adding a initialiser or hardener, which may be mixed in at this point. Mix it in well with the rest of the composition, so the polymerisation takes place homogenously throughout the mass. Note that the polymerisation reaction may release heat which could cause spontaneous ignition of some mixtures. Especially if too much hardener is added the polymerisation reaction takes place at a great rate. So, take precautions accordingly.

3) Following the instructions, shape the composition as required. If it is inserted into a casing, a thin casing is usually used to allow the solvent to migrate through the walls and evaporate.

4) Allow to dry thoroughly. Depending on the solvent, temperature, ventilation, the amount of composition used, the surface area of the shaped mass and the casing surrounding it, drying time may vary from minutes to months! Do not try to speed up drying using heat; just be patient.

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paper-and-ink literature

"Fireworks: the Art, Science, and Technique" by T. Shimizu

A standard work in the world of pyrotechnics, this book deals with many aspects of the subject. It has a extensive section dealing with commonly and less commonly used chemicals and their properties, detailed construction of many different kinds of devices, safety and the arrangement of fireworks to achieve the best effect among many other things.

"Fireworks, Principles and Practice" by reverend R. Lancaster

This is also one of the more important works on pyrotechnics and deals with a large variety of subjects. Like 'Fireworks: the Art, Science, and Technique' this book is a great source of info on diverse topics.

"Practical Introductory Pyrotechnics" by T. Peregrin.

I must admit I do not own this book, I've heard many positive comments and it seems a good buy, particularly for the beginning pyro. The author, Tom Peregrin, is well known in the internet pyro community and used to be a regular poster on the newsgroup rec.pyrotechnics.

"Ball Milling Theory and Practice for the Amateur Pyrotechnician" by Lloyd E. Sponenburgh

I build my ball mill without this book, but heard from many people that they found the book well worth it's money. It deals with the theory of ball milling and contains detailed instructions for building and operating a ball mill for pyrotechnic purposes, including instructions for casting your own media. The author, Lloyd Sponenburgh is also well known in the internet pyro community and used to be a regular poster on the newsgroup rec.pyrotechnics where he is (among other things) very helpfull in answering any questions you may have regarding his book or ball milling.

"Round stars and shells" by D. Bleser

The title says it all. All you need to know when you'd like to make a good looking round shell. It deals with star compositions, rolling the stars, assembling shells, comets, lifting and more.

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Mixing techniques

Mixing of pyrotechnic ingredients is a basic skill that every pyro must master. Mixing pyrotechnic compositions is not as simple as it may seem at a first glance and improper mixing techniques are a common cause of accidents among beginning amateur pyro's. Depending on the sensitivity and required properties of the mixture different mixing techniques may be employed. Below you'll find three descriptions of accepted methods with which most mixtures can be made.

[Diapering method](#)

[Screening method](#)

[Ball milling method](#)

Diapering method

The diapering method can be used for a wide variety of mixtures of all sensitivities. It produces very little friction and is used for mixtures as sensitive as flash as well as for less sensitive mixtures such as most fountain compositions. Up to a pound of composition may be conveniently mixed at a time (although this is strongly discouraged for powerfull and sensitive mixtures such as flash).

1. Prior to mixing, sieve the chemicals to remove clumps. Sieve each chemical separately. Break any clumps up, sieve again, and repeat this until all passes the sieve.
2. Take a large sheet of (not too thin) paper and spread it out on a flat surface.
3. Place the chemicals in the center of the paper
4. Pick up two opposite corners of the paper and alternately lift them so that the chemicals roll together.
5. Before the composition tends to fall off the paper, place the sheet back on the working surface and pick up the two other corners. Repeat the previous step with these corners.
6. Repeat as often as necessary to obtain a homogenous mixture.

Screening method

This method produces more friction than the diapering method. It is therefore unsuitable for sensitive mixtures such as flash. It is advised to use this method only for relatively insensitive mixtures such as black-powder like mixtures. Metal containing mixtures are best mixed with the diapering method as metal particles may spark with the sieve. Main advantage of the screening method is that it is fast and much less laborous than the diapering method.

1. Take a sieve with a coarse grid. It is much preferable to use a brass sieve since it will not spark.
2. Place the chemicals together in a (wooden or glass) bowl and mix them roughly with a wooden spoon.
3. Skoop the mixture on the sieve and sieve it onto a paper sheet
4. When all has passed, transfer the mixture to the bowl again and repeat the sieving as often as necessary to obtain a homogenous mixture. Small clumps that won't pass through the sieve may be broken up by applying gentle pressure with the back of a wooden spoon or a piece of paper.

Ball Milling method

Mixing with the ball milling method produces a lot of friction, shocks and maybe static electricity and is therefore dangerous. It can only be used with very insensitive mixtures and even then it must done with utmost caution and proper safety precautions. The only reason it is used (besides that is very simple and not labour intensive) is that it will produce superior mixtures: extremely homogenous and well mixed. For making lift-grade quality black powder a ball

mill seems essential. I would advise that only mixtures of potassium nitrate, charcoal and sulfur be mixed with the ball milling method. Other mixtures are usually more sensitive. Ofcourse most pure chemicals can safely be ground with the ball mill. Also see the notes on the pages dealing with [making black powder](#) and the [ball mill](#).

1. Take a ball mill
2. Insert the chemicals, wet them with an appropriate solvent
3. Turn it on and let it run for the required time to obtain a homogenous mixture.

That's basically all there is to the mixing itself. Safely operating a ball mill is a subject on it's own and is not described here. Read the linked pages above for some comments on that.

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Black powder

Black powder is the most often used mixture in fireworks. A long time ago it even was the only mixture used, since nothing else was available. While many new mixtures have been invented partially because new compounds became available, black powder still hasn't lost its special place in pyrotechnics. Partially because of tradition, partially because of its properties: it is quite safe to handle, suitable for a wide variety of uses (such as lift charges, delay charges and priming stars or fuse to name a few), and is compatible with many other often used mixtures.

Making black powder

Reasonable quality black powder can be made at home, although it is very hard if not impossible to match the quality of commercial black powder with amateur equipment. It is perfectly possible however to produce a powder suitable for lift charges, firecrackers, rocket propellants and most other things. There are several methods for [making black powder](#). Two are described on the linked page, but if you find it necessary the powder can be improved by pressing and corning. This is not described here since I found the powder good enough for all my purposes as it was without pressing.

Testing black powder

It can be very usefull to compare the quality of several types or batches of black powder, especially when you are just starting and figuring out what works best with your particular setup and materials. Just to get some idea of the quality of the first batches of black powder I made with my ball mill I did some [burn rate tests](#). They clearly show the superior quality of the black powder thus made, compared to that made with other methods I had been using then.

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Ball Mill

A ball mill is device that can be used to grind chemicals much more easily and to a finer consistency than can possibly be done by hand with a mortar and pestle. It is often usefull to grind chemicals in order to increase their surface area. This will generally increase the rate at which they react in a pyrotechnic composition and make mixtures more homogenous which results in a steady burn rate. For making good quality black powder at home a ball mill is essential, and black powder is needed in very many pyrotechnic devices.

Note: ball milling inevitably causes friction and shocks and possibly leads to static electricity buildup as well depending on the design. Ball milling of mixtures should only be attempted when an appropriate place is available to operate the mill (ie one where it causes no damage or injury in case of explosion) and it must be turned on and off remotely. Most chemicals can be milled more safely but several sets of balls and containers must be available to prevent contamination and milling of metal powders can be dangerous as they may become pyrophoric.

Materials

I used whatever I could get cheaply to construct my mill, so you will probably not be able to get the exact same materials and have to improvice somewhat.

Motor: I used to use a electrically powered drill to drive my mill, but several people have advised against it as these are not designed to operate for extended periods of time. They tend to get excessively hot and eventually fail. Old motors can be found in many places for little or no money. Washing machines for example contain durable motors and are often plentiful at scrap yards. Mine came from a pump from an old coffee machine.

Container: A piece of PVC sewer tubing works well. I use a 34 cm long 11 cm diameter piece, with two fitting end caps. PVC is hard and will not suffer from erosion as much as most other materials I've tried. This container has lasted about 150 hours of operation thus far and shows no visible signs of wear. One point of discussion is that PVC may accumulate significant amounts of static electricity during operation. I've tested if the container is able to attract small chips of polyethylene right after use, which it doesn't. I'm not entirely convinced PVC is harmless though. For some more ideas on this matter, check out [this page](#) on the charging of powders in a rotating drum. Strips of rubber from a bicycle tire are glued around the casing with hot melt glue to improve its grip on the roller.

Roller: The roller is conveniently made of PVC tubing as well. I used 2.5 cm outer diameter sewer tubing, but the diameter may be chosen depending on the speed of the motor availalable. The ratio of 2.5 cm (roller) to 11 cm (container) yields a factor 4.4. reduction in speed. As the motor operates at about 250 rpm, the container would theoratically rotate at a rate of about 60 rpm. In practice it reaches 50 rpm due to slipping. Somewhat faster would be more efficient. It used to operate at 80 rpm when I was still using the drill, and black powder would be ready in 3 hours. Now, it takes 5 hours to obtain a similar quality, but the time gain is not worth an expensive tool. The roller is coated with rubber to improve grip on the container. I did this by sliding the ends of cut inner tube from a bike tire on the ends of a piece of 2.5 cm PVC tubing. Inflating the tube allows it to slide over the PVC as the air escapes.

Media: Most of the money was spend on media. I bought 150 lead balls of 1.78 cm diameter in a hunting supplies store. They are used for reloading rifles. Lead and brass media are preferred as they don't spark. Sparks could accidentally ignite the mixture you are milling, with disastreous results. Other media such as glass, steel or ceramic can be used for pure chemicals and non explosive mixtures but not for ignitable substances. How much media will you need? I recall that it is most efficient to fill exactly half of your container with balls. My container is 11 cm diameter and 34 cm length, which took 150 lead balls of 1.78 cm diameter.

Assembling

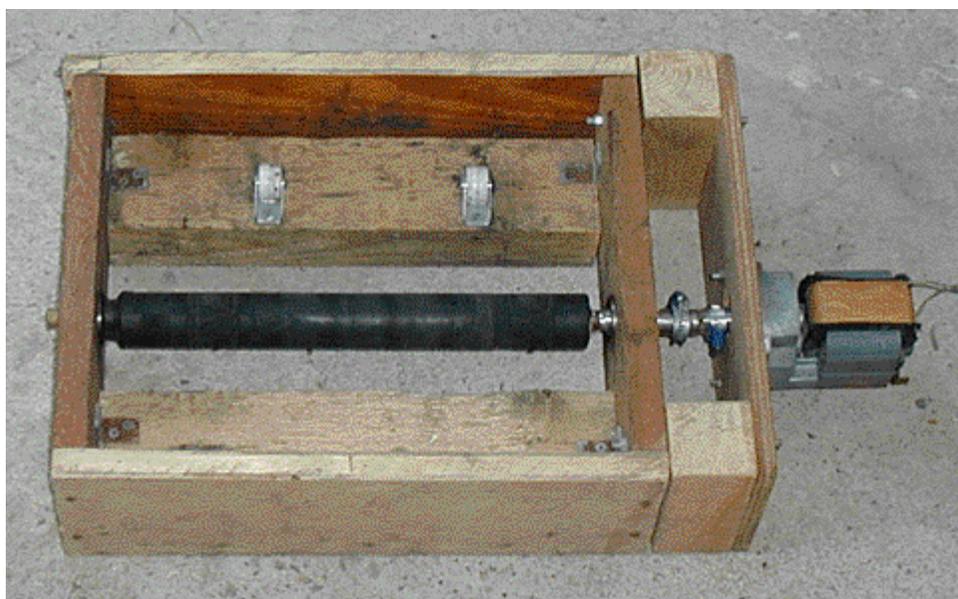
Constructing the mill is fairly simple. The [pictures](#) below illustrate the principle. The container rests on the roller and two small wheels. A copper rod lengthwise through the roller is driven by the motor on the right.

Using the mill

Ball milling can be dangerous. It inevitably causes friction and shocks that could ignite a mixture. Depending on your container and media material and the substance you are milling the process can generate static electricity as well. Milling metals can make them pyroforic. When a mixture ignites inside the mill the results can obviously be disastrous. The explosion will produce large amounts of shrapnell from the media and the milling container that can be hurled away hundreds of meters. Under no circumstances should you attempt to mill explosive mixtures such as black powder inside or near a building. Operate it on a piece of open terrain and turn the ball mill on and off remotely. Barricade it with sand bags. You can often safely mill pure compounds, but be aware that metals (which can be milled with steel media) can become pyroforic and ignite when you open the milling container (thereby letting oxygen in). Pyroforic metal powders can be very treacherous. They do not necessarily ignite immediately (although it could happen), but after some time when you think they are safe since there has been no reaction upon contact with air. When ignition occurs expect a large, extremely hot ball of flame, the burns of which can easily cause a painful death. Use your common sense when ball milling and be prepared for the worst.

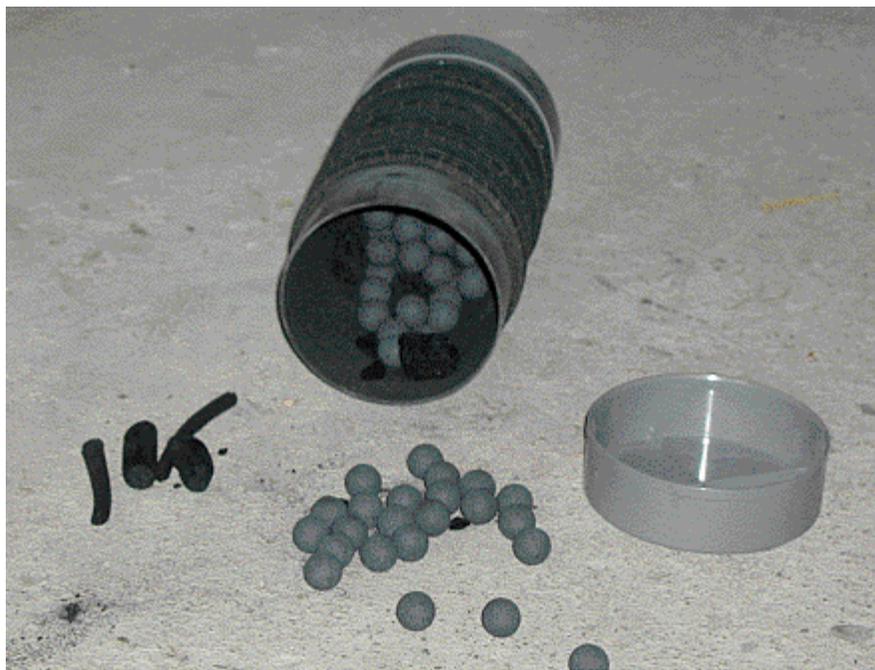
I do not know wheter the materials I chose for my ball mill (PVC and lead) generate static electricity. I have prepared many batches of black powder in my mill (using a wet process) and have not had any accidents so far. Any comments on the above design are very welcome (wfvisser@dds.nl).

Pictures



This shows the basic construction. The black horizontal bar is the rubber-covered roller, driven by the motor on the right. The two small white structures are small plastic wheels, such as are used under furniture.

The container consists of a section of PVC tubing with fitting end caps. The picture shows some of the lead media (1.78 cm diameter lead balls), and a few chunks of charcoal. These will be broken up in the mill in a matter of minutes. Strips of rubber are glued around the container as shown to improve its grip on the roller.



The container where it belongs.

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Acetone, 2-propanon

Formula: C₃H₆O

Description: Acetone is a very volatile flammable liquid which is commonly used as a solvent. Nitrocellulose and red gum both dissolve very well in acetone. The solution of nitrocellulose is called nitrocellulose lacquer. Working with acetone can be difficult as compositions dry out very quickly. The evaporation of the acetone also causes cooling of composition, sometimes even below 0 deg C. This can result in condensation of water.

Hazards: Acetone is very volatile and flammable. Acetone vapour is heavier than air and spreads over the ground. Only work with acetone outside or in a well ventilated area.

Sources: Acetone can usually be bought at any paint store. Making acetone at home is very impractical and unnecessary as it can be bought just about anywhere at low cost.

Antimony trisulfide, realgar

Formula: Sb₂S₃

Description: Antimony trisulfide is a fuel which is sometimes used in glitter compositions, fountain compositions and flash powder. For the latter purpose however it is used less and less as it is very poisonous and can usually be replaced by sulfur or completely omitted. Flash compositions containing antimony trisulfide are very sensitive to friction, shock, and static electricity.

Hazards: Antimony trisulfide should never be used in any mixture containing chlorates or spontaneous ignition may occur. Mixtures with antimony trisulfide and perchlorates are very sensitive to friction and shock and extra caution should be exercised when handling these mixtures. These mixtures are best avoided at all. Wear proper protective clothing including a dust mask, when working with compositions containing antimony trisulfide as it is very poisonous.

Sources: Antimony trisulfide is sometimes sold as a pigment in (art) paint stores, but is not used very commonly these days due to its toxicity. It can be made at home by fusing a stoichiometric mixture of antimony metal and sulfur. This is a very dangerous operation since extremely toxic fumes will form and it should only be performed with proper safety precautions taken.

Aluminum

Formula: Al

Description: Aluminum powder is one of the most often used fuels in pyrotechnics. A wide range of effects are possible with different types of powder, depending on particle size, shape and impurities. The finest powders (sometimes referred to as 'dark' aluminum) such as the well known 'german dark' are used mainly in flash. Fine aluminum is also used in small percentages in some rocket fuels. Coarser powders are generally used for spark effects. Depending on the particles shapes, sizes and compositions many different effects such as flitter, glitter, firefly and snowball can be achieved.

Hazards: A dust mask should be worn when working with aluminum powder. Mixtures containing nitrates and aluminum powder are prone to heating up spontaneously and may ignite, especially when wet. This is caused by the reduction of the nitrate by aluminum, forming amides. These very basic compounds react further with aluminum powder in a very exothermic reaction that can cause spontaneous ignition. An ammonia smell is often produced in this reaction. Adding 1 to 2% boric acid to compositions containing nitrates and aluminum is common practice and will often prevent spontaneous ignition, although this should never be relied upon. It is advisable to avoid using water to bind such compositions. Red gum or shellac with alcohol or nitrocellulose lacquer are preferred binder and solvents.

Sources: Aluminum powder is sometimes sold as a pigment in (art) paint stores. This powder, known as 'aluminum bronze', is a flaky powder with a stearin coating. It is quite expensive but readily available and a source for small quantities. Aluminum grit and turnings can sometimes be found in machine shops where aluminum is processed. If fine enough this can be used as is, but it can also be ball milled into flakes. These flakes are quite reactive as they have a large surface area and can be used for several effects. Aluminum powder can also be made by sanding aluminum chunks. I've heard of people building a machine to do this, and the results can be quite good depending on the sanding paper used and the setup.

Ammonium chloride

Formula: NH_4Cl

Description: Ammonium chloride is used in smoke compositions. When heated ammonium chloride decomposes to HCl and NH_3 , both gasses. These recombine in the air to give a smoke consisting of fine particles of ammonium chloride.

Hazards: Ammonium chloride based smoke is irritating to the eyes and lungs as it contains some remaining HCl and NH_3 . Ammonium chloride itself is not poisonous and is even used in some type of candy. According to Shimizu ammonium chloride forms an exception to the rule that ammonium compounds should not be mixed with chlorates. Due to the lower solubility of potassium chlorate (compared to ammonium chlorate) no ammonium chlorate . I personally would still use these mixtures with great caution (or avoid them) since it seems inevitable that small amounts of ammonium chlorate will still form. The lower solubility of potassium chlorate will make it the -main-product in a double decomposition reaction but not the -only- product.

Sources: Ammonium chloride solution is easily prepared by neutralising ammonia solution with hydrochloric acid. It is advised to use a slight excess of ammonia. That is to make sure no remaining acid will be present in the ammonium chloride obtained on evaporation and crystallisation. Otherwise traces of the acid solution may be enclosed in the crystals, possibly leading to spontaneous ignition of mixtures made with it.

Ammonium nitrate

Formula: NH_4NO_3

Description: Ammonium nitrate is an oxidiser. It is very hygroscopic and therefore not used very often in fireworks. It finds some use in composite propellants, but performance is not as good as perchlorate based propellants.

Hazards: Large masses of ammonium nitrate have been known to explode on some occasions although it is very unresponsive. Smaller quantities are less likely to detonate. The risk of detonation increases when ammonium nitrate is molten or mixed with fuels such as metal powders or organic substances. Ammonium nitrate should never be mixed with chlorates as this may result in ammonium chlorate formation, possibly leading to spontaneous ignition. Mixtures of metal powders and ammonium nitrate are likely to heat up spontaneously and may ignite, especially when moist. This can sometimes be prevented by the addition of small amounts of boric acid (1 to 2%), but in general it is better to avoid these mixtures at all. The hygroscopic nature of ammonium nitrates makes this problem worse (also see [aluminum](#)).

Sources: Ammonium nitrate solution can be prepared by neutralising ammonia solution with nitric acid. It is advised to use a slight excess of ammonia. That is to make sure no remaining acid will be present in the ammonium nitrate obtained on evaporation and crystallisation. Otherwise traces of the acid solution may be enclosed in the crystals, possibly leading to spontaneous ignition of mixtures made with it. Large quantities of ammonium nitrate can also be cheaply bought as fertilizer. In the Netherlands a fertilizer called 'kalkammonsalpeter' is sold. This consists of ammonium nitrate mixed with 'mergel', a mineral consisting mainly of calcium carbonate. The ammonium nitrate can be extracted with water.

Ammonium perchlorate

Formula: NH_4ClO_4

Description: Ammonium perchlorate is an oxidiser used in a large number of compositions. Very impressive color compositions can be made with it, but their burn rate is often too low for use in star compositions. For lancework and torches slow burning is an advantage and it is therefore commonly used in these items. Ammonium perchlorate is also used in composite rocket propellants, including the propellants used in the solid propellant boosters used for the space shuttle. The decomposition products of ammonium perchlorate are all gasses which is very beneficial for rocket propellants.

Hazards: Ammonium perchlorate can detonate by itself, although it is not very sensitive. Larger amounts and mixtures of ammonium perchlorate with metal powders or organic substances are more likely to detonate.

Sources: Ammonium perchlorate is usually bought from chemical suppliers or from dedicated pyro suppliers. Fine ammonium perchlorate powder is a regulated substance in most countries and cannot easily be bought or transported. Since it is such a useful chemical in pyrotechnics it can be worth the time and effort to try to prepare it at home. This can be done by first making [sodium perchlorate](#) followed by double decomposition with ammonium chloride (other ammonium compounds can be used). The preparation of sodium perchlorate is most easily accomplished by electrolysis, the procedure for which is described elsewhere on this page.

Barium carbonate

Formula: BaCO_3

Description: Barium carbonate is used both in white and green color compositions. When chlorine donors are present in a composition a green color will result from the formation of BaCl^+ in the flame. Without chlorine donors BaO will be formed which emits white light. Barium carbonate is convenient to use in chlorate based color compositions since it will neutralize residual acid which reduces the risk of spontaneous ignition.

Hazards: Most barium compounds are very poisonous, especially the more soluble barium compounds such as the chlorate and nitrate. A dust mask should be worn at all times when working with barium carbonate.

Sources: Barium carbonate is cheaply available in kilogram quantities from ceramic supply shops. However, this material is often contaminated with small amounts of barium sulfide which are left over from the production process. Therefore, ceramics grade barium carbonate should never be used in mixtures incompatible with sulfides such as chlorate based mixtures. Barium carbonate is not easily made at home.

Barium chlorate

Formula: BaClO_3

Description: Barium chlorate is used as an oxidiser in green color compositions. Fierce burning and high color purity compositions can be made with it.

Hazards: Barium chlorate is poisonous and a dust mask should be worn at all times when handling it. Barium chlorate should never be mixed with sulfur or sulfides or allowed to come in contact with mixtures containing sulfur or sulfides since this could result in spontaneous ignition. (Sulfur reacts with water and air to form small amounts of sulfuric acid. Sulfuric acid and chlorates react producing ClO_2 , an explosive gas which will ignite many organic materials on contact). Mixtures made with barium chlorate are often especially sensitive to friction and shock (even more so than potassium chlorate based mixtures) and should be handled with extra care.

Sources: Barium chlorate is usually purchased from chemical suppliers or from dedicated pyro suppliers. It can be

made at home from [sodium chlorate](#) and barium chloride by double decomposition. Barium chlorate can also be prepared from barium chloride by electrolysis in a process analogous to that used for preparing sodium chlorate.

Barium nitrate

Formula: BaNO₃

Description: Barium nitrate is used as an oxidiser in both white and green color compositions. When chlorine donors are present in a composition a green color will result from the formation of BaCl⁺ in the flame. Without chlorine donors BaO will be formed which emits bright white light. Barium nitrate is seldom used as the sole oxidiser in green color compositions. It is usually combined with perchlorates to improve the color and increase the burning rate.

Hazards: Barium nitrate is poisonous and a dust mask should be worn at all times when handling it. Mixtures of metal powders and barium nitrate sometimes heat up spontaneously and may ignite, especially when moist. This can usually be prevented by the addition of small amounts of boric acid (1 to 2%). It is advisable to avoid using water to bind such compositions. Red gum or shellac with alcohol or nitrocellulose lacquer are preferred binder and solvents (also see [aluminum](#)).

Sources: Barium nitrate may be prepared from nitric acid or ammonium nitrate and barium carbonate, which is available from ceramic supply stores.

Barium sulfate

Formula: BaSO₄

Description: Barium sulfate is used as a high-temperature oxidiser in some metal based green color compositions.

Hazards: Unlike many other barium compounds, barium sulfate is not very poisonous due to its low solubility in water.

Sources: Barium sulfate may be precipitated from a solution of a soluble barium salt, such as barium nitrate or chloride, and a sulfate. Magnesium and potassium sulfate are both cheaply available as fertilizer and are convenient to use. The precipitated barium sulfate is a very fine powder which may be rinsed by repeated washings with hot water, settling and decanting. A final washing in the filter with acetone or ethanol will allow it to dry quickly. Do not use sulfuric acid to precipitate barium sulfate as this may result in the inclusion of acid droplets in the precipitated particles which can lead to spontaneous ignition of some mixtures.

Boric acid

Formula: H₃BO₃

Description: Boric acid is a white powder which is used as an additive to compositions containing aluminum or magnesium and a nitrate. The metal powder can reduce the nitrate to an amide which will react with the metal powder in a very exothermic reaction that can lead to spontaneous ignition of the composition. This process is often accompanied by a smell of ammonia and is most likely to occur with wet compositions. Addition of a few percent boric acid can often prevent this reaction from taking place since it neutralizes the very basic amides forming ammonia and a borate. It is also advisable to avoid using a water soluble binder for these composition. Using red gum or shellac with alcohol or nitrocellulose lacquer is safer.

Hazards: Boric acid is not particularly toxic or dangerous.

Sources: Boric acid is cheaply and in kilogram quantities available from ceramic supply shops. It is also sold in many drug stores at a somewhat higher price, but since only small quantities are needed the price is not really important.

Calcium sulphate

Formula: $\text{CaSO}_4 \cdot x \text{H}_2\text{O}$ where $x = 0, 2, 3$ or 5

Description: The trihydrate is commonly known as plaster of paris. The dihydrate occurs as a mineral known as gypsum. Calcium sulphate can be used as a high temperature oxidiser in orange color compositions. Excellent strobe compositions can be made with it.

Hazards: Calcium sulphate is not particularly toxic or dangerous.

Sources: Plaster can be used as is in strobe compositions, but is better to remove the water which is easily accomplished by heating.

Charcoal

Formula: mixture with variable composition.

Description: Charcoal finds widespread use in pyrotechnics. Many types of charcoal exist, each with its own properties. Charcoal made from willow or grapevine is considered great for black powder, while paulownia and pine charcoal are commonly used for spark effects. The particle size and the process used to make the charcoal also play an important role in the quality of the charcoal for a specific purpose. Very fine charcoal floats in air and is therefore sometimes referred to as 'airfloat'.

Hazards: Fine charcoal dust is easily breathed in, and a dust mask should be worn when working with it. Freshly prepared charcoal can be pyrophoric even when not powdered and it must be allowed to stand for a day at least before it is used to prepare compositions with.

Sources: Barbeque briquettes are mixed with clay and are not suitable for making black powder. It will however produce long lasting sparks and can be used for that purpose. Charcoal is easily prepared at home, although it can be hard to get reproducible results. Simply placing some twigs (1 to 2 cm diameter) in a steel pan with a lid and heating it on a camping stove will make reasonable quality charcoal. It is important to make sure you don't heat for too long. Good charcoal looks like the original twigs but black with a brown tinge. It should not have split lengthwise and it should break easily with a sharp snap. The rings in the wood should still be visible. It is possible to tell when the charcoal is done by the smoke emerging from the pan. During 'pyrolysis', the process of heating the wood in the absence of oxygen, smoke will form. After some time less smoke will form and that's the time to stop heating. Leave the lid on the pan while the charcoal cools to exclude air. Freshly made charcoal can be pyrophoric and it is certainly a good idea to leave the cooled charcoal exposed to the air for a day or two before further processing.

Clay

Formula: Mixture with variable composition.

Description: Clay is used for nozzles and plugs. Of all the types of clay in use 'bentonite' and 'kaolin' are probably the most common. Ground kitty litter is a cheap alternative and works well.

Hazards: Clay is not particularly toxic or dangerous.

Sources: As mentioned, kitty litter can be a cheap source of clay. A cheap variety of non-clumping kitty litter can be ground (mortar and pestle or ball mill) and sieved to obtain a fine powder which is easily pressed into a compact pellet. Bentonite and kaolin clay are also available from ceramic supply stores.

Colophonium

Formula: Mixture of compounds, mainly abietic acid, $C_{20}O_2H_{29}$

Description: Colophonium is an alcohol soluble resin which is sometimes used as a binder. It is not used very often since it is expensive and doesn't have much adhesion capacity.

Hazards: Colophonium is not particularly toxic or dangerous.

Sources: Artist paint stores often sell colophonium. It is also used by violin players, for the treatment of wooden floors and in the paper industry.

Copper acetoarsenite, Paris green

Formula: $Cu_3As_2O_3Cu(C_2H_3O_2)_2$

Description: Copper acetoarsenite is a green powder which is used in blue color compositions. It can produce great blues but it is also very poisonous and is used less and less for that reason. Today alternatives are available that will produce deep blues with less poisonous and cheaper compounds.

Hazards: Copper acetoarsenite is very poisonous and should only be handled wearing a dust mask. Smoke from compositions containing this compound should not be inhaled. It is best to avoid the use of this compound altogether as several safer alternatives have become available in the past decades.

Sources: Copper acetoarsenite was used in the past as a pigment known as emerald green, kings green or vienna green. Nowadays it is no longer used and it is very hard to find a paint supplier that still has it. It can be prepared at home but extreme caution must be exercised since arsenic compounds are very poisonous. The following preparation originates from Shimizu: "300 g of copper sulphate is dissolved in 1000 ml water, to which 250 g of glacial acetic acid is added; This solution is named 'A'. Then 200 g of sodium carbonate and 200 g of erseious acid are added to 1000 ml water and boiled to form a solution, this is named 'B'. B is added little by little to A with constant stirring. Carbon dioxide gas is generated with active bubbling. When all the solution B has been added, it is boiled for about 30 minutes, when copper acetoarsenite appears gradually as green particles in the solution. The mother liquor is removed by vacuum filtration, and then green substance, copper acetoarsenite, is washed with water until the sulphate ion dissapears; it is then dried. The yield is about 180 g."

Copper benzoate

Formula: $Cu(C_6H_5COO)_2$

Description: Copper benzoate is a fuel which is used in some blue color compositions. It is not used very often as it is more expensive than most alternatives.

Hazards: Copper benzoate is poisonous and should be handled wearing a dust mask

Sources: Copper benzoate is easily prepared at home from a solution of sodium or potassium benzoate and a soluble copper salt. When these solutions are added together a green precipitate of copper benzoate forms. This is filtered, thoroughly rinsed with hot water and left to dry.

Copper chromite

Formula: $CuCr_2O_4$

Description: Copper chromite is employed as a catalyst in certain rocket propellants. It is typically added in 1 to 5% quantities to whistle or composite rocket fuels which increases the burn rate. A range of other catalysts exist which can often be substituted for copper chromite. Examples are Fe_2O_3 and MnO_2

Hazards: Copper chromite is poisonous and should be handled wearing a dust mask.

Sources: Copper chromite is very hard to make or obtain other than from dedicated pyro chemicals suppliers.

Copper(II)oxide

Formula: CuO

Description: Copper oxide is a black powder employed in blue color compositions in combination with chlorine donors.

Hazards: Copper(II)oxide is poisonous and should be handled wearing a dust mask.

Sources: Copper(II)oxide is usually available from ceramic supply stores. It is also easily prepared at home as follows: Add a solution of sodium or potassium hydroxide to a solution of a soluble copper(II) compound (copper sulfate for example). This will yield a blue gel-like precipitate of copper(II)hydroxide. Then bring to solution to a boil. The precipitate will turn black and powdery. Boil for a minute or two to complete the reaction and allow the black copper(II)oxide precipitate to settle. Then decant the liquid. Add some boiling hot water to the precipitate, stir and allow to settle again. Then decant and repeat 5 more times. This will remove all soluble impurities from the copper(II)oxide. Then the precipitate is filtered and allowed to dry.

Dextrine

Formula: mixture of polysaccharides

Description: Dextrine is one of the most commonly used binders in pyrotechnics as it is very cheap and readily available. It is water soluble and can produce rock hard stars.

Hazards: Colophonium is not particularly toxic or dangerous.

Sources: Dextrine is easily prepared from starch. Potatoe and corn starch will both work fine. The starch is spread out on a sheet in a layer about 1 cm thick and placed in the oven. The oven is then heated to 220°C for several hours. The dextrine will turn slightly yellowish brown. One way to check if all the starch has been converted is to dissolve a small sample in boiling hot water and add a drop of KI₃ solution. A blue color indicates presence of starch, which means the conversion hasn't completed yet. KI₃ solution is conveniently prepared by dissolving a crystal of elemental iodine in a potassium iodide solution.

Ethanol

Formula: CH₃CH₂OH

Description: Ethanol is used as a solvent. Red gum and shellac, two common binders both dissolve in ethanol well. Ethanol/water mixtures are also often used since the ethanol increases the 'wetness' of the water (it reduces the surface tension of the water) and reduces the solubility of common oxidisers.

Hazards: Ethanol is flammable and volatile. Ethanol vapour is heavier than air and spreads over the ground. Provide adequate ventilation when working with ethanol

Sources: Chemically pure ethanol can be quite expensive due to increased tax, unless it is used for laboratory purposes. Denaturated alcohol (usually a mixture of ethanol and methanol) has been made undrinkable and therefore a lot cheaper. It can be used for pyro purposes. Some types of denaturated alcohol exist with other chemicals mixed in besides methanol to make it undrinkable and recognisable as such (colorants etc). I have no idea what these extra additives are and whether they can cause problems in compositions. I have been using 'spiritus' (a well known type of

denaturated alcohol in the Netherlands) for several years without problems.

Iron

Formula: Fe

Description: Iron powder is used for spark effects, mainly in fountains and sparklers. It produces golden yellow branching sparks. Not every iron alloy will work equally well. Iron alloys with a high carbon content generally work best. Stainless steel will produce hardly any sparks.

Hazards: Iron needs to be protected before use in pyrotechnic compositions. Otherwise it will corrode and render the composition useless or even dangerous. Iron containing compositions are generally best kept dry and not bound with water soluble binders. Iron can be coated with linseed or tung oil. The latter was used in ancient China (and may still be used today). Linseed is very convenient to use and easy to obtain. Blackpowder-like compositions (ie Charcoal/sulfur/saltpeter based) with added metal, such as they are often used in fountains, are more sensitive than the composition without added metal. Extra caution, especially when pressing or ramming, should be excersised.

Sources: Iron turnings can often be had for free from places were iron is used for construction. Drilling, sawing etc produces a powder with wide range of particles. This powder is treated with mineral oil to remove oil and grease, sieved, and then coated with linseed oil.

Iron oxide (red)

Formula: Fe₂O₃

Description: Red iron oxide is used as a catalyst in composite and whistling rocket propellant formulations. It is also added to some glitter formulations and used for 'thermite', a mixture that produces enormous amounts of heat, forming molten iron.

Hazards: Red iron oxide is not particularly toxic or dangerous.

Sources: Common rust is not iron oxide. It is a mixture of oxides and hydroxides. A cheap source for red iron oxide is the ceramics supply shop.

Lead tetraoxide

Formula: Pb₃O₄

Description: Lead tetraoxide, sometimes called 'lead minium', is used to make crackling microstars. The composition is very sensitive, explosive and poisonous. It is in fact one of the most dangerous mixtures used commonly in modern pyrotechnics. An alternative mixture based on bismuth trioxide exists (which is less poisonous), but the high price of bismuth trioxide restricts its use.

Hazards: Lead tetraoxide, like most lead compounds, is extremely poisonous. Lead is an accumulative neurotoxin and extreme care should be taken to prevent direct contact. Lead tetraoxide may be absorbed by inhalation and ingestion. Wear a respirator, gloves, and protective clothing.

Sources: Lead tetraoxide may be prepared from a solution of lead nitrate and sodium hydroxide. Note that the procedure involves extremely corrosive and poisonous chemicals and should only be attempted by those who have access to (and know how to use) the right equipment and can handle the waste properly. Prepare a concentrated solution of sodium hydroxide by dissolving 300 grams of sodium hydroxide in water. The solution will heat up during this. To prevent it from boiling suddenly add only small portions at a time. When all has dissolved, allow it to cool down to room temperature. Dissolve 50 grams of lead nitrate in 200 ml of water, and slowly add the sodium hydroxide

solution to this solution while stirring continuesly. A white precipitate will form first, which will turn orange when all sodium hydroxide solution has been added. Stir this solution well for another hour, and then allow the lead tetraoxide to settle. Carefully decant the supernatant, add boiling hot water to the residue, stir, allow to settle and decant again. Repeat this 5 more times. Then filter and rinse the lead tetraoxide in the filter several times with hot water.

Manganese dioxide

Formula: MnO_2

Description: Manganese dioxide can be used as a catalyst in composite and whistling rocket propellant formulations. A thermite-like mixture can also be made with it. The manganese dioxide thermite burns more slowly than the iron oxide based mixture with a bright white glow.

Hazards: Manganese dioxide is poisonous and leaves brown stains on glassware etc. The stains can be removed with dilute hydrochloric acid (ofcourse, only when the stained object is not attacked by it).

Sources: Manganese dioxide can be obtained from old batteries or from the ceramics supply store. The manganese dioxide in batteries is mixed with several other compounds from which it must be separated. An easy, though messy way to do this is as follows: Find a couple of depleted carbon-zinc batteries. Only carbon-zinc type batteries will do. Do not use other types such as rechargable or lithium based batteries. These, especially the rechargable ones, contain extremely dangerous and/or poisonous compounds such as cadmium, mercury and metallic lithium. Carbon-zinc batteries may contain small amounts of mercury as well, especially the older types, so precautions should be taken to prevent skin and eye contact and to prevent breathing or swallowing of dust. So: wear your dust mask, glasses, gloves and old clothing. Then carefully take the battery apart. You'll find a greyish white (zinc oxide) or metallic coating (zinc metal) inside, depending on wheter the battery is empty or not. This surrounds a black, sometimes wet, mass. This black stuff contains among other things the manganese dioxide. Peel the coating off and save the black mass. There is also a black rod inside attached to the anode. This is a graphite rod and can be safed for chlorate (and maybe perchlorate) preparations. We'll assume you use 2 batteries from here on. (if not, adjust amounts accordingly). Place the black mass in 200 ml of 30% hydrochloric acid. The manganese dioxide will slowly dissolve, giving off chlorine gas. Chlorine gas is dangerous: it attacks the lungs and is poisonous. Do this outside or better yet: in a fume hood if you have one. Allow the manganese dioxide several days to dissolve. The solution is then filtered which should yield a clear solution of manganese(III)chloride. In a separate container dissolve 200 grams of sodium hydroxide in a liter of bleach. Add the manganese(III)chloride solution slowly to the bleach/sodium hydroxide solution. This results in a brown precipitate of manganese dioxide which is filtered, rinsed several times with boiling hot water and dried.

Magnalium

Formula: Alloy of magnesium and aluminum, usually 50:50. Sometimes written: MgAl

Description: Magnalium is a very brittle alloy of magnesium and aluminum. Some common uses are in for spark effects, in strobing compositions and in crackling stars. It is commonly alloyed in

Hazards: Magnalium dust is harmful and a dust mask should be worn when handling fine dust. Mixtures containing nitrates and magnalium sometimes heat up and may ignite spontaneously, especially when moist. This can usually be prevented by treating the magnalium with potassium dichromate. This is done by boiling the magnalium in a 5% potassium dichromate solution. Adding fine potassium dichromate powder to such compositions may also help.

Sources: Magnalium can be made at home. Plan well and prepare yourself for working with molten metals that may ignite if you plan to make it at home. If the metal ignites expect it to burn very brightly and hot. Explosions are not common but may occur if the hot melt is allowed to contact water or oxidisers. Do it outside and away from anything flammable. If it ignites don't try to extuingish it but get away from the burning mass and let it burn out and cool before approaching it. Don't look directly into the burning metal as it may damage your eyes. Start by melting aluminum in a stainless steel container. The molten metal should be covered with a blanked of inert gas. In this case neither nitrogen nor carbon dioxide will function as an inert gas. It is best to get a cylinder of argon gas at a welding supply store.

Using an electric furnace for the melting is very convenient and allows good control over the temperature. To the molten aluminum magnesium is added in solid form. The melt should be stirred from time to time. When all the magnesium has melted, the melt is allowed to solidify. It is then easily crushed up in smaller chunks with an heavy hammer. These chunks are crushed further and sieved. It can also be ball milled into a fine powder using steel media but this can be dangerous since the metal powder can become pyrophoric.

Magnesium

Formula: Mg

Description: Magnesium powder is used in a wide variety of compositions, both for spark effects and 'normal' fuel purposes. Relatively coarse magnalium is used for spark effects. In flares and some bright colored star compositions it functions as a normal fuel. It is superior to aluminum in color compositions since MgCl₂ and MgO are more easily vaporised than the corresponding aluminum compounds. This reduces the amount of black-body radiation and improves the color purity.

Hazards: Magnesium dust is harmful and a dust mask should be worn when handling fine dust. Mixtures containing nitrates and magnesium sometimes heat up and may ignite spontaneously, especially when moist. This can usually be prevented by treating the magnesium with potassium dichromate. This is done by boiling the magnalium in a 5% potassium dichromate solution. The magnesium will turn brown when this is done. Adding fine potassium dichromate powder to such compositions may also help.

Sources: Making magnesium at home is very difficult. Magnesium can be bought in boating supply stores. It is used to prevent corrosion of a ships hull. For that purpose it is welded to the hull. The lower position of magnesium in the electrochemical series will make the magnesium corrode before the steel will. Making such a block of magnesium into a fine powder will not be easy. Filing or cutting and ball milling may be tried. Ball milling of metals can be dangerous however since the metal can become pyrophoric.

Methanol

Formula: CH₃OH

Description: Methanol is used as a solvent, much in the same way ethanol is used. Red gum and shellac, two common binders both dissolve in methanol. Methanol/water mixtures are also often used since the methanol increases the 'wetness' of the water (it reduces the surface tension of the water) and reduces the solubility of common oxidisers.

Hazards: Methanol is flammable, volatile and toxic. Methanol vapour is heavier than air and spreads over the ground. Provide adequate ventilation when working with methanol

Sources: Methanol is often more cheaply and easily available than ethanol because it is toxic and no extra taxes are charged for it. It finds use in a certain type of camping stove and can often be bought in camping supply stores.

Nitric acid

Formula: HNO₃

Description: Nitric acid is not used in pyrotechnic compositions but it can be used to prepare a variety of useful nitrates from carbonates, hydroxides, oxides or free elements. It is used in the explosives industry in the preparation of a lot of commonly used explosives (eg TNT, RDX, PETN, nitrocellulose). Most high explosives have no use in fireworks, though nitrocellulose is used in some fireworks compositions as an acetone soluble binder.

Hazards: Nitric acid is corrosive. The fumes are dangerous to the lungs, eyes and skin. Skin will be stained yellow upon contact. Avoid all contact with both liquid and fumes. Wear eye and skin protection (lab apron, gloves, safety

glasses, etc). In some reactions (especially those with metals) a brown gas will develop: nitrogen dioxide. It is very toxic, corrosive and will attack your lungs badly. Only work with nitric acid with adequate ventilation and proper protective clothing. Don't use any solutions more concentrated than 60%. Don't try to prepare high explosives at home and don't allow any organic material to contact nitric acid accidentally because that may result in the formation of dangerously explosive and/or sensitive materials.

Sources: It is possible to prepare nitric acid in several ways. It can also be bought at some drug stores. Here (in the Netherlands) it is sold under its Latin name, 'acidum nitricum'. Other places where it is sold is at professional gardening suppliers and at welding shops (it is used to passivate stainless steel after welding). One way to prepare it is by distilling a mixture of sulphuric acid and sodium nitrate. This process is dangerous and requires some equipment. This method is probably too dangerous for the average amateur pyro. Another possible method is by precipitating barium sulphate from a barium nitrate solution by adding sulphuric acid. What remains is a nitric acid solution. It should be possible to prepare quite concentrated solutions by using concentrated sulphuric acid and a saturated (-not-hot!) barium nitrate solution. It is important that the sulphuric acid is added to the barium nitrate solution and not the other way around. The mixing of the liquids will produce heat and if the barium nitrate solution is added to the sulphuric acid it could cause sudden boiling and splatting. Therefore, add the sulphuric acid slowly to the barium nitrate while constantly stirring. Allow the mixture to cool from time to time if it gets too hot. A white precipitate of barium sulphate should form. The mixture is then filtered through a sintered glass filter to obtain clear solution of nitric acid.

Nitrocellulose

Formula: nitrated cellulose, mixture of compounds

Description: Nitrocellulose is used as a binder in pyrotechnic compositions. It is also used in some items without any other oxidisers or fuels. In other fields of pyrotechnics than fireworks it is widely used as a propellant, sometimes mixed with nitroglycerine and other materials (so called double- or triple base propellants).

Hazards: Nitrocellulose can detonate in large quantities. It is also extremely flammable and must be handled as if it is a mixed composition (which it is in fact, on the molecular level, unlike most pure chemicals). Pure nitrocellulose is thermally unstable and will decompose over time. Double and triple base powders contain nitroglycerine and are probably best avoided for use in fireworks.

Sources: Nitrocellulose is sold in gun shops to those with the proper licences in some countries. Double and triple base powders seem to be most common though. A less nitrated but usable form of cellulose, called celluloid, is also used in some household items: ping-pong balls. This may be a source for small amounts. Celluloid is also used for film but that is getting a little scarce these days with digital cameras taking over the market. It is probably too expensive for pyro uses anyway. Finally, it is possible to make nitrocellulose at home. The procedure is too lengthy to describe well here, but it involves treating cellulose (preferably cotton or paper) with a mixture of sulfuric acid, nitric acid and water. The product is then washed extensively and stabilised. Properly stabilising the product at home may be difficult and commercial nitrocellulose is preferred for that reason.

Parlon

Formula: $(C_4H_6Cl_2)_n$

Description: Parlon is a acetone-soluble polymere that is used as a chlorine donor and binder. It is a good example of one of the new chemicals that has become available in the past few decades for use in compositions.

Hazards: Parlon is not particularly dangerous.

Sources: Parlon seems to be available from dedicated pyro suppliers only.

Potassium benzoate

Formula: $KC_7H_5O_2$

Description: Potassium benzoate is commonly used in whistle compositions. It is a white powder

Hazards: Potassium benzoate is not particularly dangerous.

Sources: Potassium benzoate can be prepared from benzoic acid and potassium carbonate or hydroxide. Benzoic acid is not very soluble, but both potassium carbonate and hydroxide are. Dissolve 140.2g potassium carbonate or 56.1g potassium carbonate in 250 ml water, and add 146g benzoic acid. Bring the mixture to a boil. If potassium carbonate is used, CO_2 gas will evolve. Continue boiling until all benzoic acid has dissolved, occasionally adding some water to make up for what has evaporated. When all benzoic acid has dissolved, continue boiling until the first crystals of potassium benzoate are observed (ie the saturation point has been reached). Then allow the solution to cool to room temperature. Potassium benzoate will crystallise in needle shaped crystals. Filter, and rinse the crystals twice with ice-cold water. The crystals may be dried in an oven at 100 deg C.

Potassium chlorate

Formula: $KClO_3$

Description: Potassium chlorate is a very common oxidiser in pyrotechnics, even though it has some treacherous properties and other oxidisers would sometimes be safer to use. Part of the reason of its popularity in commercial pyrotechnics is that it is cheap and easily available. The large scale production of this compound made the first quality colored fireworks possible, about a century ago.

Hazards: Potassium chlorate is toxic, and breathing protection should be worn when handling fine powder. Compositions made with potassium chlorate tend to be more sensitive than those based on nitrates and perchlorates and should therefore be handled accordingly. Potassium chlorate, or any chlorate for that matter, should never be used in combination with sulfur and sulfides. Mixtures containing both are very sensitive and may spontaneously ignite. In general, when using chlorates great care should be taken to avoid contamination of other compositions or tools. Also read the [general safety](#) page for more information on this problem.

Sources: Potassium chlorate can be prepared at home. For this purpose, [sodium chlorate](#) is prepared first by electrolysis. It may also be obtained as a herbicide in some countries (France, for example) Then, by double decomposition with potassium chloride, potassium chlorate is prepared from this solution. The product is recrystallised, dried and powdered.

Potassium dichromate

Formula: $K_2Cr_2O_7$

Description: Potassium dichromate is a bright orange crystalline substance that is used to treat magnesium powder. The treatment makes magnesium more resistant to spontaneous reactions that could result in lower reliability of the mixture or spontaneous ignition.

Hazards: Potassium dichromate is toxic and a carcinogen. It should be handled with extreme care and proper protective clothing.

Sources: Potassium dichromate seems to be available from chemical suppliers and dedicated pyro suppliers only.

Potassium nitrate

Formula: KNO₃

Description: Potassium nitrate is probably the most extensively employed oxidiser in pyrotechnics. It used for a wide variety of applications, the most important of which is probably in the manufacture of black powder. Potassium nitrate is a white powder or long needle-like crystals.

Hazards: Potassium nitrate is not particularly dangerous or toxic.

Sources: Potassium nitrate is used as fertilizer. As such it can be bought cheaply and in large quantities. This can be used as is, but for more delicate color compositions it may be required to purify it by recrystallisation. Another possible source for potassium nitrate is 'stump remover', though this is somewhat more expensive. Alternatively, potassium nitrate can be prepared from other chemicals. For example from nitric acid and potassium carbonate or hydroxide (acid-base reaction), or sodium nitrate and potassium chloride (fractional crystallisation). At all times, make sure the product is free of acid since this makes the risk of accidental ignition much greater.

Potassium perchlorate

Formula: KClO₄

Description: Potassium perchlorate is a very common oxidiser in pyrotechnics. Composition based on perchlorates tend to be less sensitive than those based on chlorates, and perchlorates can be used with sulfur and sulfides. For these reasons potassium perchlorate is much preferred above chlorates. Drawback is its slightly higher price.

Hazards: Potassium perchlorate is toxic, and breathing protection should be worn when handling fine powder.

Sources: Potassium perchlorate can be prepared at home. For this purpose, [sodium perchlorate](#) is prepared first by electrolysis. Then, by double decomposition with potassium chloride, potassium perchlorate is prepared from this solution. The product is recrystallised, dried and powdered.

Polyvinyl chloride

Formula: [C₂H₃Cl]_n

Description: Like parlon and saran, PVC is a polymeric chlorine donor and fuel. It can be used in the form of a fine powder or as a solution in tetrahydrofuran (THF). It is sometimes used as a binder, but it is very brittle. Small amounts of plasticiser (dioctyl phtalate is common) may be added to improve the mechanical properties.

Hazards: PVC itself is not particularly dangerous or toxic. Dioctyl phtalate is a suspected carcinogen however and THF is a very flammable and volatile liquid.

Sources: As an alternative to the PVC powder available from chemical suppliers and dedicated pyro suppliers, PVC glue may also be used. It is usually sold in hardware stores and comes in two varieties: gelling or gap-filling and normal. Both are essentially a concentrated solution of PVC. I have no experience with the gelling variety, but the normal variety can successfully be used in compositions. The gelling variety may be better suited for pyro purposes since it seems it contains more PVC. Another possibility is to use 'Sculpy' or 'Fimo' clay. These modelling clays consist of PVC with a large amount of plasticiser. The plasticiser may affect the color of a composition negatively, but reasonable results can still be obtained with it. It can simply be kneaded into a composition with some effort. This type of clay is usually hardened by heating it in an oven, but do not be tempted to do this with pyrotechnic mixtures as they may ignite.

Red gum

Formula: Mixture of compounds.

Description: Red gum, or accaroid resin, is one of the most commonly used binders. It is made from the excretions of a certain tree native to Australia. Red gum is soluble in ethanol and acetone.

Hazards: Red gum is not particularly dangerous or toxic.

Sources: Red gum may be bought in artistic painting supply stores.

Saran

Formula: chlorinated polymere.

Description: Saran is used as a chlorine donor and fuel much in the same way as parlon and PVC are. It can also serve as a binder, in which case acetone is a suitable solvent.

Hazards: Saran is not particularly dangerous or toxic.

Sources: Saran seems to be available from chemical suppliers and dedicated pyro suppliers only.

Shellac

Formula: Mixture of compounds of average elemental composition $C_{16}H_{26}O_4$

Description: Shellac has been in use as a binder and fuel for many centuries. It is a somewhat brittle but strong resin that dissolves in ethanol and acetone, albeit slowly. It is sometimes claimed that shellac is a superior fuel for use in colored compositions.

Hazards: Shellac is not particularly dangerous or toxic.

Sources: Shellac is available from artistic painting supply stores. They usually have several varieties, of which 'orange shellac' works well.

Sodium benzoate

Formula: $NaC_7O_2H_5$

Description: Sodium benzoate is a white solid that is used as a fuel. It's most common use is in 'whistle mix', a mixture of potassium perchlorate and either sodium or potassium benzoate.

Hazards: Sodium benzoate is not particularly dangerous or toxic.

Sources: Sodium benzoate can be made from sodium carbonate (soda) or sodium hydroxide and benzoic acid which is often more easily available than it's salts. Benzoic acid is only sparingly soluble in water. Dissolve either 425 g hydrated sodium carbonate (common household soda) or 30 g sodium hydroxide in water. Add 100 g of benzoic acid and boil the solution. The benzoic acid will slowly dissolve. During boiling, occasionally add water to make up for what has evaporated. If sodium carbonate was used, carbon dioxide gas will evolve. After all the benzoic acid has dissolved, continue boiling allowing the water to evaporate until crystallisation begins. Then stop heating and allow the solution to cool slowly to room temperature. Needle-shaped crystals of sodium benzoate will form upon cooling. Cool the solution further to 0 deg C, filtrate and rinse the crystals with ice-cold water. Purify the product by recrystallisation from water.

Sodium chlorate

Formula: $NaClO_3$

Description: Sodium chlorate is hardly ever used in pyrotechnics, since it is very hygroscopic. It finds occasional use in composite rocket propellants. It is however very useful as a starting point in the preparation of several other (less hygroscopic) chlorates for which reason it is included here.

Hazards: Sodium chlorate is toxic, and breathing protection should be worn when handling fine powder. Compositions made with sodium chlorate tend to be more sensitive than those based on nitrates and perchlorates and should therefore be handled accordingly. Sodium chlorate, or any chlorate for that matter, should never be used in combination with sulfur and sulfides. Mixtures containing both are very sensitive and may spontaneously ignite. In general, when using chlorates great care should be taken to avoid contamination of other compositions or tools. Also read the [general safety](#) page for more information on this problem. Acidic solutions containing chlorates generate a very poisonous and explosive gas, ClO_2 .

Sources: Sodium chlorate can be prepared at home. It involves electrolysing a sodium chloride solution under certain circumstances. A description of the process, cell and anode design, etc. for home production may be found in the [chlorate and perchlorate](#) section of this page. In some countries, France for example, sodium chlorate may be obtained as a herbicide.

Sodium nitrate

Formula: NaNO_3

Description: Sodium nitrate finds occasional use as an oxidiser in flare and tracer compositions because of the high efficiency of light emission that can be obtained with it, but its high hygroscopic nature limits its use. Sodium nitrate can be used to prepare potassium nitrate, a much less hygroscopic and more often used oxidiser.

Hazards: Sodium nitrate is not particularly dangerous or toxic.

Sources: 95% pure sodium nitrate is available as a fertilizer. In the Netherlands this fertilizer is sold under the name 'chilisalpeter'. If required, it can be easily purified by recrystallisation.

Sodium perchlorate

Formula: NaClO_4

Description: Sodium perchlorate is hardly ever used in pyrotechnics, since it is very hygroscopic. It finds occasional use in composite rocket propellants. It is however very useful as a starting point in the preparation of several other (less hygroscopic) perchlorates for which reason it is included here.

Hazards: Sodium perchlorate is toxic, and breathing protection should be worn when handling fine powder.

Sources: Sodium perchlorate can be prepared at home. It involves electrolysing a sodium chlorate solution under certain circumstances. A description of the process, cell and anode design, etc. for home production may be found in the [chlorate and perchlorate](#) section of this page.

Strontium carbonate

Formula: SrCO_3

Description: Strontium carbonate is used in combination with chlorine donors to produce red colors. It also acts as an acid neutraliser, for which reason it is preferred in chlorate based compositions (which may spontaneously ignite when traces of acid are present).

Hazards: Strontium carbonate is not particularly dangerous or toxic.

Sources: Strontium carbonate is cheaply available in kilogram quantities from ceramic supply shops. However, this material is often contaminated with small amounts of strontium sulfide which are left over from the production process. Therefore, ceramics grade strontium carbonate should never be used in mixtures incompatible with sulfides such as chlorate based mixtures. Strontium carbonate is not easily made at home.

Strontium nitrate

Formula: $\text{Sr}(\text{NO}_3)_2$

Description: Strontium nitrate is an oxidiser commonly employed in red color compositions in combination with chlorine donors.

Hazards: Strontium nitrate is not particularly dangerous or toxic.

Sources: Strontium nitrate may be prepared from nitric acid or ammonium nitrate and strontium carbonate, which is available from ceramic supply stores. Use an excess of strontium carbonate to ensure complete neutralisation of acid and recrystallise the product from a slightly alkaline solution to prevent the inclusion of acid solvent droplets in the crystals.

Strontium sulfate

Formula: SrSO_4

Description: Strontium sulfate is used as a high-temperature oxidiser in some metal based red color compositions.

Hazards: Strontium sulfate is not particularly dangerous or toxic.

Sources: Strontium sulfate may be precipitated from a solution of a soluble strontium salt, such as strontium nitrate or chloride, and a sulfate. Magnesium and potassium sulfate are both cheaply available as fertilizer and are convenient to use. The precipitated strontium sulfate is a very fine powder which may be rinsed by repeated washings with hot water, settling and decanting. A final washing in the filter with acetone or ethanol will allow it to dry quickly. Do not use sulfuric acid to precipitate strontium sulfate as this may result in the inclusion of acid droplets in the precipitated particles which can lead to spontaneous ignition of some mixtures.

Sulfur

Formula: S

Description: Sulfur has always been used extensively in pyrotechnics. It serves as a fuel, and reduces the ignition temperature of mixtures. It also tends to increase the burning rate and friction or shock sensitivity of most mixtures.

Hazards: Sulfur can increase the sensitivity of some mixtures, especially those based on chlorate or perchlorate oxidisers. Mixtures of chlorates and sulfur are also known to ignite spontaneously and should therefore be avoided at all times (also read the [safety](#) section). Mixtures of perchlorates and sulfur are less likely to ignite spontaneously but are still very sensitive and need to be treated with extreme caution. Burning sulfur produces sulfur dioxide gas, inhalation of which should be avoided because it is extremely poisonous.

Sources: Sulfur is available from agricultural supply stores where it is sold as a fungicide under the name 'dusting sulfur'. It is a fine powder mixed with a few percent of calcium carbonate. The calcium carbonate may disturb delicate color compositions, but for most purposes dusting sulfur works well. If a purer form of sulfur is required, sulfur may also be obtained from drug stores sometimes. However, these often sell 'flowers of sulfur', which has been purified by

sublimation and which contains some acid. This needs to be neutralised before use as it could cause spontaneous ignition. To do this, allow 100g of this sulfur to soak in a liter of water/household ammonia (1:5). Stir well occasionally and measure the pH. It should still be alkaline after two days, after which time the sulfur may be filtered and washed with hot water to remove the ammonia. Check the pH of the washing water while filtering. After it has become neutral, flush the water away with ethanol and allow the sulfur to dry. Mix the dry powder with 2% magnesium carbonate to neutralise any acid that may be formed in reactions with the atmosphere.

Sulfuric acid

Formula: H₂SO₄

Description: Sulfuric acid itself finds no use in pyrotechnics, but it can be used in the preparation of an number of usefull compounds for which reason it is included here.

Hazards: Sulfuric acid and its fumes are extremely corrosive. Wear proper protective clothing (gloves, apron and a face shield are minimal) and provide adequate ventilation when working with it. Reactions with metals often produce flammable hydrogen gas (hydrogen). The presence of acid can cause spontaneous reactions in many pyrotechnic mixtures and should at all times be avoided. When working with sulfuric acid, have no chemicals or compositions nearby to prevent contamination. Make sure all traces of acid in chemicals produced with sulfuric acid are removed if they are to be used in pyrotechnics compositions.

Sources: Sulfur is available from agricultural supply stores where it is sold as a fungicide under the name 'dusting sulfur'. It is a fine powder mixed with a few percent of calcium carbonate. The calcium carbonate may disturb delicate color compositions, but for most purposes dusting sulfur works well. If a purer form of sulfur is required, sulfur may also be obtained from drug stores sometimes. However, these often sell 'flowers of sulfur', which has been purified by sublimation and which contains some acid. This needs to be neutralised before use as it could cause spontaneous ignition. To do this, allow 100g of this sulfur to soak in a liter of water/household ammonia (1:5). Stir well occasionally and measure the pH. It should still be alkaline after two days, after which time the sulfur may be filtered and washed with hot water to remove the ammonia. Check the pH of the washing water while filtering. After it has become neutral, flush the water away with ethanol and allow the sulfur to dry. Mix the dry powder with 2% magnesium carbonate to neutralise any acid that may be formed in reactions with the atmosphere.

Titanium

Formula: Ti

Description: Metallic titanium is used to produce bright white sparks. The particle size and shape of the titanium will affect the color and duration of the sparks.

Hazards: Titanium can spark if hit with other metals (especially steel) or against itself. Blackpowder-like compositions containing titanium, such as often used in fountains, are notably more sensitive than mixtures without titanium.

Sources: Titanium shavings and curls are sometimes available from places where titanium metal is worked. These are often contaminated with oil which can be removed by washings with white gas or acetone. Titanium curls can be heated in an oven to make them more brittle, which facilitates crushing them into a powder. Care must be taken when attempting this however as the titanium may ignite when heated too much.

Zinc

Formula: Zn

Description: Metallic zinc is used in rocket propellants, for spark effects and in white smoke compositions. Zinc

powder is quite heavy and zinc-based stars often require heavier lift or burst charges to propell them.

Hazards: Zinc powder can spontanously heat up when wet.

Sources: Zinc powder is used in paints for the protection of steel. Spray cans containing an suspension of zinc powder are commonly sold in hardware stores. The zinc powder may be extracted by emptying the spray can in a large container, allowing the powder to settle, decanting the solvent and paints and repeated washing with paint thinner or acetone.

Zinc oxide

Formula: ZnO

Description: Zinc oxide is used to produce white smoke.

Hazards: Zinc oxide is not particularly toxic or dangerous.

Sources: Zinc oxide is usually available as a white pigment called 'zinc white' in artistic paint stores. It can also be prepared by igniting a piece of zinc sheet.

Preparing chlorates

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Chapter 3: [Thermal decomposition of hypochlorites](#)

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Chapter 1: Introduction

On an industrial scale, chlorates are prepared by electrolysis. Electrolysing a solution of a chloride at elevated temperatures yields a chlorate. This method can be downscaled quite easily for amateur pyro purposes. Other methods of chlorate manufacture exist that may be of interest for small scale use. They are usually less efficient but the economy of the process is not as important for amateur pyro purposes as it is for industrial setups. A second method for example consists of heating a solution of hypochlorite. Sodium and calcium hypochlorite are both quite easily available as bleach and pool chlorinating agent respectively. Upon heating, the hypochlorite will decompose into both chloride and chlorate. The chlorate is separated and purified. Although slow and laborous, the method is simple and requires very little equipment. In the past chlorates were produced even on an industrial scale by bubbling chlorine gas through a hot hydroxide solution. This process is not very well suited for amateurs since chlorine gas is very dangerous to handle. The process is also extremely inefficient, for which reason it was abandoned quite soon after the electrochemical method became feasible at industrial scale.

Chapter 2: Electrolytic preparation

The electrolysis is carried out in a diaphragmless cell, containing a solution of a chloride. Several chlorides may be used, but the use of sodium chloride has many advantages. Sodium chlorate is easily converted to a number of other chlorates by metathesis reactions. The most commonly used chlorates in pyrotechnics, potassium and barium chlorate, can both be made in this manner. Potassium chloride and barium chloride may also be used to obtain the respective chlorates directly, but this has many disadvantages as will be discussed below. Only sodium chlorate can be used in the manufacture of perchlorates, due to its high solubility.

Ammonium chloride should never be used, and should in fact not even be present in the cells in trace amounts. It could result in the formation of two dangerously sensitive and explosive compounds, nitrogen trichloride (NCl_3) and ammonium chlorate (NH_4ClO_3). The formation of both of these compounds should be avoided at all times. Not only

can they explode by themselves when present in significant quantities, they can also lead to spontaneous ignition of pyrotechnic mixtures contaminated with even small amounts.

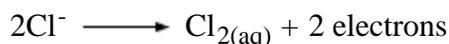
2.1 theory

Mechanism of chlorate formation

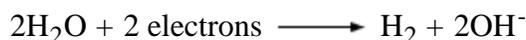
The reactions taking place in chlorate cells are not fully understood even today. A summarised description of the process will be given here, and the interested reader is referred to the [literature](#) listed below for a more extensive description.

The theory of Foerster and Mueller regarding the reactions in chlorate cells, developed about 80 years ago, is the most accepted. The following reactions are said to take place at the electrodes:

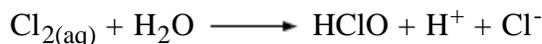
At the anode:



At the cathode:

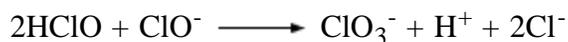


The dissolved chlorine gas can then react with water to give hypochlorous acid:



From this reaction it can be seen that if the chlorine does not dissolve but escapes to the atmosphere, no H^+ will be generated to neutralise the OH^- formed at the cathode and the pH of the electrolyte will increase.

The hypochlorous acid thus formed will react in acid-base equilibrium reactions with water to give hypochlorite ions and chlorine gas (dissolved). The exact concentrations of dissolved Cl_2 , ClO^- and HClO depend on the pH, temperature and pressure among other things. In the solution, chlorate will be formed (mainly) by the following reactions:



and



These reactions take place at a rather slow rate. Since this reaction pathway is the most efficient one as we will shortly come to see, the conditions in the cell are usually optimised to increase their reaction rate. The pH is kept within a range where HClO and ClO^- are simultaneously at their maximum concentration (which is at around pH=6). The temperature is kept between 60 and 80 degrees centigrade, which is a good compromise between the temperatures required for a high reaction rate, low anode and cell body corrosion and high chlorine solubility (remember the chlorine evolved at the anode has to dissolve in the solution to start with). Many cells also have a large storage tank for electrolyte in which the electrolyte is kept for a while to give these reactions some time to take place.

Alternatively, chlorate may also be formed by oxidation of hypochlorite at the anode as follows:



Oxygen is evolved in this reaction, which means a loss of current efficiency (the energy used for oxidising the oxygen in water to the free element is lost when the oxygen escapes to the atmosphere). When the reaction routes are worked out, it turns out that following this path 9 faradays of charge are required to produce 1 mole of chlorate, whereas only 6 faradays are required to do that following the route mentioned earlier. Therefore, optimising the conditions for that route improves current efficiency.

To prevent the products from being reduced at the cathode again, a membrane around the cathode was employed in the past. Today, small amounts of chromates or dichromates are added. A layer of hydrated oxides of chromium will then form around the cathode effectively preventing hypochlorite and chlorate ions from reaching the cathode surface.

Finally, it should be mentioned that the reactions forming perchlorates do not take place until the chloride concentration has dropped to below about 10%. Therefore, cells can be constructed and operated in such a way that chlorate is produced almost exclusively. The chlorate can then be purified and fed into a perchlorate cell. Depending on the type of anodes used in the chlorate cell, the purification step may also be skipped and the electrolysis continued until all chloride has been converted into perchlorate. Although slightly less efficient (and therefore not used a lot in industrial setups), this is much less laborious and therefore probably the preferred method for home setups.

Cell voltage

The current through a cell is related to the reaction rate. Therefore, to obtain a constant reaction rate that suits the cell design, a constant current is usually employed. The voltage over the cell will then fluctuate depending on conditions and cell design. The power consumed by the cell is the product of current and voltage, according to equation $P = I * V$. From that it can be seen that reducing the voltage over the cell results in a lower power consumption, an important fact for industrial operations. The factors influencing the cell voltage have been thoroughly investigated. Most important are the anode - cathode spacing, the concentration of the electrolyte, the surface area and materials of the electrodes, the temperature and the pH. Without going into details, the cell voltage usually lies in the range 3.5 - 4.5 volts. Of this, approximately 3 volts are required to get the oxidation of chloride to chlorate to take place (and the hydrogen reduction at the cathode), while the rest is used to overcome the resistance of the cell, according to Ohm's law $V=I*R$. From this law it can be seen that there are two ways to maintain a constant current through a cell: either the voltage over it may be varied or its resistance may be changed. Adjusting the voltage over a cell to maintain a constant current can be done manually or with an electronic circuit. If the power supply does not allow voltage adjustment (such as old PC power supplies or battery chargers for example) or the required electronics are not available, adjusting the resistance of the cell is another option. This could in principle be done by adjusting each of the factors mentioned earlier, the most practical of which is probably the anode-cathode distance. By increasing the distance between the electrodes the resistance of the cell is increased, which reduces the current through the cell. One thing to keep in mind when doing this is that with decreasing resistance, the heat generated in the cell is increased. Depending on the anode material used it may then be necessary to cool the cell to prevent excessive erosion, more on that later.

2.2 Cell construction

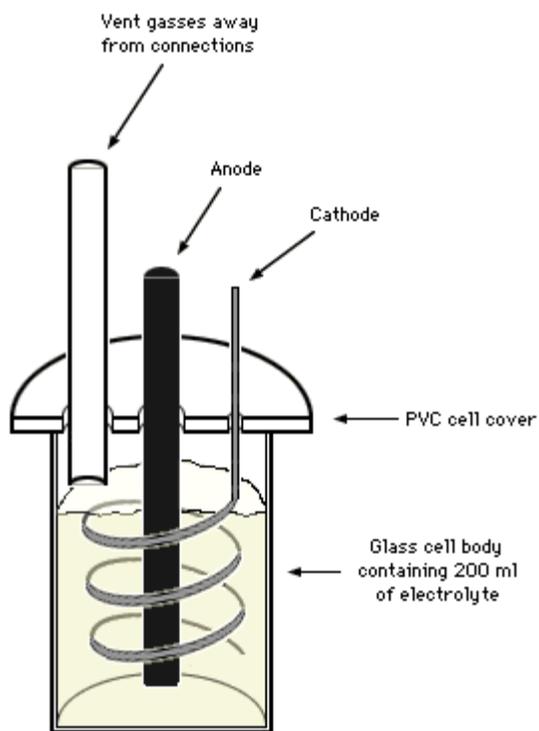
Cells can range in complexity from a glass jar with a nail and a old battery electrode to well designed, corrosion resistant cells with thermostats, pH control, circulating electrolyte and coulometers. Even the simplest of cells will work, but it will require more maintenance. If the chlorates are going to be prepared on a more or less regular basis, it probably pays to spend some more time designing a cell. It will also improve efficiency somewhat, but unlike in industrial setups where high efficiency is mandatory to be able to compete, the home experimenter can do with less efficient cells. The two main disadvantages of a low efficiency is that it takes more time for the conversion to complete, and that more electricity is required. To give some indication of the power consumption of the process: typical figures for industrial cells lie in the range 4.5 to 5.5 kWh per kg of sodium chlorate.

In this section some of the things to consider when building and designing chlorate cells will be discussed. The reader

can design his own cell based on the information given. An example of a cell, the small test cell I currently use to experiment with, has been given but it is by no means perfect, and it is probably better to design your own. The example has merely been given to illustrate some principles.

2.3 An example

The example given here consists of a small cell, of 200 ml electrolyte volume. The cell is normally operated with graphite or graphite substrate lead dioxide anodes. Platinum sheet has also been tried with, unsurprisingly, good success. The electrolyte consists of sodium chloride with either some potassium dichromate or potassium fluoride added, depending on whether graphite or lead dioxide anodes are used. The cathode consists of a stainless steel wire spiraling down. The wire is corroded where it is not submerged, so it has to be replaced occasionally. The connections to the anode and cathode are made outside the cell but do corrode from the gasses and electrolyte mist. This is partially prevented by leading the gasses away from the connections with a vent tube, as shown in the picture. Covering the connections with hot melt glue also helps, but the heat generated in a faulty connection may cause the hotmelt to melt.. The temperature is controlled by placing the cell in a water bath, which acts as a heat sink. If the temperature is too low, styrofoam isolation is provided. The cell is operated outside, causing the temperature to fluctuate between day and night. The pH is checked about twice a day and adjusted if necessary with hydrochloric acid. The power source used is an old computer power supply. The output voltage can be regulated within certain limits and this is done to maintain a current of about 4 amperes. An other model computer power supply was used previously that did not allow control over the output voltage. Current adjustment was done by widening or narrowing the cathode spiral, effectively reducing or increasing the anode-cathode distance.



Theoretically, if 100% efficiency could be reached, the cell would have the capacity to convert approximately 35 grams of sodium chloride to 64 grams of sodium chlorate per day. Using a metathesis reaction with potassium chloride this would yield 74g of potassium chlorate. In practice the average yield is about 40 grams of potassium chlorate a day from which an efficiency of 55% can be calculated.

2.4 Cell volume

This is the main factor affecting a cells capacity, provided the power supply can provide the necessary current. As a rule of thumb no more than 2 amperes per 100 ml of electrolyte must be passed through a chlorate cell. Under more optimal conditions a higher amperage may be tolerable, still maintaining reasonable efficiency whereas in less optimal conditions 2 amperes may be too high and a lot of chlorine will be lost, leading to lower efficiency and rising pH. A current of 2 amperes will convert approximately 0.73 gram of sodium chloride to 1.32g of sodium chlorate per hour (assuming 100% efficiency). After extracting, metathesis reactions and recrystallising that will yield 1.53 g potassium chlorate. So, for example, to produce 100 grams of potassium chlorate a day at least $100 \text{ grams} / 1.53 \text{ grams} / 24 \text{ hours} * 100 \text{ ml} = 272 \text{ ml}$ of electrolyte is required. To maintain that rate of conversion the cell will then require $272 \text{ ml} / 100 \text{ ml} * 2 \text{ amperes} = 5.44 \text{ amperes}$. If a cell is less efficient than 100%, which every cell is, increase these figures proportionally (so at 50% efficiency: $100\% / 50\% * 272 \text{ ml} = 544 \text{ ml}$ of electrolyte, consuming 10.88 amperes of current to maintain the same rate of production). The example cell described above contains 200 ml of electrolyte. Thus, it should be operated at a current of 4 amperes, and the maximum daily yield is $100/272 * 200 = 74 \text{ g}$ of potassium chlorate after processing the electrolyte. These figures were also mentioned in the cell description without explanation.

2.5 Cell body materials

One of the main problems in chlorate cells is the corrosiveness of the electrolyte. Only very few materials do not corrode when in contact with the electrolyte or its fumes. Most metals corrode, many plastics will and even glass does under some circumstances.

Some metals, such as steel, can be used if they are protected from corrosion in some way. For that purpose it can be coated with a resistant material such as teflon or some types of rubber, or it can be 'cathodically protected'. This means it is used as a cathode. The negative potential prevents the steel from being oxidised if the current density (current per unit of surface area) on the steel is high enough.

Some metals, such as titanium, zirconium, tantalum and niobium, form a protective film when they are in contact with the electrolyte. This prevents them from further corrosion, and they therefore find extensive use in industrial setups (particularly titanium because it is the cheapest). For amateurs the difficulties in working with these metals and their high price restricts their use somewhat. In small scale setups glass and plastics such as PVC are more easily available, easier to work with and much cheaper.

The table below gives some idea of how well a number of materials stand up to corrosion. The column 'protected' lists how well metals resist corrosion when cathodically protected. The column 'unprotected' lists materials used as is.

material	corrosion resistance when unprotected	corrosion resistance when cathodically protected
Iron	--	+
Stainless steel	-	+
Titanium	++	++
Copper	--	++
Brass	--	+
Tantalum	++	++
Platinum	++	++
Aluminum	--	+ -
PET	++	X
Poly ethylene	+	X
Poly propylene	+	X
PVC	++	X
Rubber	+ -	X
Hot melt glue	+ -	X
Styrene	-	X
Graphite	+	+
Silicone rubber	--	X
Concrete	+	X
Glass	++	X
Ceramics	++	X
Wood	--	X
Polyester	-	X

2.6 Electrode materials

The range of suitable electrode materials is very limited. Especially the anode material is critical. The positive charge on the anode promotes oxidation and the evolving oxygen attacks many anode materials. Several anode materials have been considered over the years. Today's main options are listed below along with a short description.

Anode materials

Graphite: graphite is cheap and easy to obtain. It does however corrode at a comparatively fast rate. This makes it necessary to replace the anodes every so often and to filter the electrolyte before further processing which can be difficult and laborious due to the small size of the carbon particles. Graphite is not suitable for making perchlorates. When the chloride concentration of the electrolyte drops to the point where perchlorate formation begins (about 10% w/v), the graphite begins to oxidise at a great rate, yielding no or only traces of perchlorate. Cells operating with graphite anodes must also be maintained at a relative low temperature to limit anode erosion, which translates to a lower cell capacity. Graphite rods can be found in old manganese dioxide-zinc batteries or in welding shops where they are sold as 'gouging rods'. They can be treated with linseed oil to reduce corrosion. A practical method for the home experimenter has been devised by Rich Weaver, and is well described on Mike Brown's page. Old battery electrodes do not need to be treated with linseed oil.

Platinum: The obvious disadvantage of platinum is its high price. However, platinum anodes corrode only at a very slow rate and are suitable for perchlorate production. They therefore provide an almost ideal anode material. High efficiency can be reached with platinum and processing of the electrolyte is greatly simplified.

Lead dioxide: Lead dioxide provides an economical alternative to platinum. Lead dioxide anodes can be made at home. This takes some work and effort, but the anodes are cheap, fairly resistant to corrosion even at higher temperatures and are suitable for perchlorate production. More information on [lead dioxide electrodes](#) is given elsewhere on this homepage.

Manganese dioxide: Another oxide that is conductive and resistant to oxidation. It is made by thermal decomposition of manganese nitrate pasted onto a substrate. This type of anode seems quite promising for amateur pyro use. For more information, the user is referenced to patents in the literature list below. If anyone has experiences with these anodes and their preparation I'd be most interested to hear about them.

DSA: DSA stands for Dimensionally Stable Anode. This is the common term used to refer to anodes consisting of a layer of noble metal oxides (usually RuO_2 and TiO_2) coated onto a substrate, usually titanium. This type of anode is finding increased use in industrial cells because of its comparatively low cost when compared to platinum and its resistance to corrosion. Some of the chemicals required to manufacture these anodes (particularly RuCl_3 and tetrabutyl titanate, $\text{Ti}(\text{OBu})_4$) are expensive and perhaps difficult to handle safely. However, if the chemicals can be obtained and suitable equipment is available, the procedure to make the anode seems fairly straightforward and may be an option. For the preparation of these, the reader is referenced to the literature. Again, I'd be most interested in anyone's experiences with this type of anode.

Magnetite: This has found use in industry in the past, but is rarely used nowadays. It corrodes, but not very quickly and it can be used for perchlorate manufacture. The anodes are made by melting and casting $\text{FeO} \cdot \text{Fe}_2\text{O}_3$ into the required anode shapes. I have little literature available on this material, so it is not further discussed here.

Cathode materials

Both stainless and mild steel find widespread use as cathode materials. Brass and copper may also be used. Each of these metals is protected to a certain extent by the negative charge present on the cathode as long as they are submerged and the current per surface area is high enough. Unsubmerged parts of the cathode corrode at a high rate

however due to the action of evolving gasses and droplets of cell electrolyte.

It seems that under some conditions the chromium in stainless steel can dissolve, even though the cathode does not seem to corrode. A yellow electrolyte is the result from which barium chromate can be precipitated even if no chromate was added, which will be described later (see [processing the electrolyte](#)). The presence of chromates could lower the efficiency of cells employing lead dioxide anodes.

Finally, contamination of the final product with copper (from brass or copper erosion products) can be dangerous when the product is to be used in pyrotechnic purposes. Although this is unlikely to be a great problem since the impurities are usually removed easily and completely by filtration (as will be described later) it is good to be aware of the possibility.

2.7 pH and temperature control

Although not essential for chlorate manufacture, controlling the temperature and pH will increase cell efficiency and therefore the capacity of a cell. Temperature control can be anything from a sophisticated thermostat and heating element (or a cooling element) to simple insulation around the cell or a cold water bath. As mentioned earlier, part of the electric energy is lost as heat in the cell. Small cells operating at high currents can sometimes reach temperatures of 80 to 90 deg C. Though high temperatures will improve efficiency, temperatures as high as that will also increase anode corrosion and it is therefore usually considered better to maintain a temperature in the range 60 to 80 deg C to get the best of both worlds. Graphite anodes tend to erode faster than other types though, especially at higher temperatures, and cells employing these are therefore usually operated at 40 deg C to limit anode erosion.

Like temperature control, pH control is not essential for chlorate manufacture. Efficiency is improved greatly however if the pH is kept within the range 5.5 - 6.5 (slightly acidic) as explained in the theory section. Graphite anodes also tend to erode faster at high pH, so maintaining the pH will extend graphite anode life. In commercial setups pH control is done manually by periodic additions of hydrochloric acid. Automated pH control seems to be difficult and expensive to realise. If anyone devices a practical method of doing this, I'd be interested to hear about it.

2.8 Preparing the electrolyte

When just starting a first batch of chlorate a fresh electrolyte has to be prepared. When the cell has been operated before, the electrolyte from the previous cell is available to prepare the electrolyte for a new batch. Also, the material left behind from the extraction and purification steps can be added to the next cell as it may contain some residual chlorate. That way no product left in the solution after processing is lost.

As mentioned, it is common to use sodium chloride to prepare sodium chlorate first, which is then converted to potassium or barium chlorate later. Even though both compounds may be prepared directly from potassium or barium chloride, using sodium chloride as a starting material has advantages. Mainly, it makes processing of the electrolyte much easier since sodium chlorate is very soluble. It is therefore easily separated from insoluble impurities which are almost always present. It will be assumed that sodium chloride is used. If for some reason the use of other compounds is desired, the procedure and amounts may need to be adjusted.

Preparing fresh electrolyte

1. Prepare a saturated solution of sodium chloride. Take about 40 grams for every 100 ml of solution and bring the solution to a boil. Then allow to cool to room temperature again. Some sodium chloride will crystallise as the solution cools. The solution is then filtered to obtain a clear saturated solution.
2. Optionally, 2 to 4 g/l of potassium dichromate, potassium chromate, sodium chromate or sodium dichromate may be added to improve efficiency. These compounds are suspected carcinogens, so if you choose to add any, know the hazards involved and act accordingly. If lead dioxide anodes are used, do not add potassium dichromate as it will only reduce efficiency. Instead, 2 to 4 g/l of sodium or potassium fluoride may be used. Although not carcinogenic, the

fluorides are nasty compounds as well and should be handled properly.

3. Finally, the pH of the solution can be adjusted. A pH of around 6 is optimal, but anything between 5.5 and 6.5 is reasonable. The pH can be increased by addition of sodium hydroxide solution and it can be decreased by adding hydrochloric acid. Do not use too concentrated solutions for adjusting the pH. A concentration of 2% (w/v) for both solutions is convenient to work with.

Recycling old electrolyte

When electrolyte from a previous batch of chlorate is available the following steps can be used to recycle the electrolyte.

1. If the electrolyte is not clear but has solid particles in it, filter to remove these. See the section on [filtering](#) below.
2. dissolve any impure chlorate from the purification and extraction steps.
3. Now, re-saturate the solution with sodium chloride. The procedure mentioned above in step 1 of 'preparing a fresh electrolyte' may be used.
4. The chromate, dichromate or fluoride if added is still present so does not need to be replenished. The pH should be readjusted, like in step 3 for preparing a fresh solution above.

2.9 Operating the cell

Voltage and current

As explained in the [theory](#) section the voltage over the cell may vary. The current should be kept more or less constant at a value determined by the cell design. As a rule of thumb, supply 2 amperes of current per 100 ml of electrolyte. If graphite anodes are used it is better to supply less current since that will increase anode life (30 mA per square centimere of anode surface area is typical). A constant current supply is ofcourse the most convenient to use for regulating current, but manually adjusting the voltage from time to time also works well. The current usually only changes very gradually, and the precise value is not very critical. In any case, measure the current at regular intervals and record them. That information is required to determine when a batch is complete, as described below in the paragraph 'running times'.

Maintaining optimal conditions

As explained, the pH of the electrolyte will tend to rise. Also, some of the water will evaporate and some will be consumed in the reaction. The temperature may also vary with ambient temperatures. For good efficiency these variables must be kept within certain limits.

Every once in a while, make up for evaporated and consumed water. This can be done with water, but it is better to use a saturated sodium or potassium chloride solution. That way, the chloride concentration will be kept at a higher level which improves efficiency. It will also prevent excessive formation of perchlorate, and in graphite anode based cells it reduces anode wear.

The pH will rise during operation of the cell, and it is best to lower the pH regularly to a value of about 6. A high pH value is best corrected by adding hydrochloric acid occasionally. If too much HCl is added, it may be corrected with sodium hydroxide solution. The pH is self correcting to a certain extend as well, since at very low pH the cell will produce more chlorine gas. This will then escape, raising the pH again. Measuring the pH of the solution can be done

with common pH paper. However, if the paper is simply dipped directly into the electrolyte the hypochlorite present will usually bleach the paper making a measurement impossible. This problem can be overcome by boiling a sample of the solution for 5 minutes and measuring the pH of that. The boiling destroys the hypochlorite.

The temperature will usually reach a more or less constant value quickly. If the cell is placed outside, the temperature may vary between night and day and between seasons of course, so then some sort of control may be necessary to maintain the optimum. Usually, cooling is necessary but it will depend on the specific cell design as explained in the theory section.

Running times

The time required to convert a certain amount of chloride to chlorate depends on the current and the efficiency. The latter can vary dramatically from cell to cell and it is therefore not possible to state precise running times. It is however possible to calculate the required running times for a hypothetical cell operating with 100% current efficiency. The calculation will show that the conversion of one mole of chloride to chlorate requires 160.8 amperage hours. So, for example, a cell containing 100 grams of sodium chloride will require $100/58.6 * 160.8 = 274.4$ Ah if it operates at 100% efficiency. For a current efficiency other than 100%, increase the running times in proportion (to convert 100g of NaCl with 80% current efficiency one needs $274.4/80*100 = 343$ Ah). So, if a current of 3 amperes flows through the cell, it requires $274.4 / 3 = 91.47$ hours (91 hours, 28 minutes) to finish.

2.10 Processing the electrolyte

When done, the product must be extracted from the electrolyte and the electrolyte can be recycled for the next batch (see [preparing the electrolyte](#)).

Filtering

The electrolyte usually contains suspended solid particles, even though they are not always visible. Suspended particles can be detected with the use of the Tyndall effect. Shine a bright flashlight through the side of a glass container containing the solution. If no suspended particles are present the light beam cannot be seen going through the solution. If suspended particles are present they will scatter the light and make the beam visible.

Usually, the impurities consist of erosion products of the anodes, the cell walls, and the unsubmerged parts of the cathodes. These particles may be very small and are not always easily removed with common filtering paper. Filtering through a layer of diatomaceous earth (sold in shops for aquarium supplies) in a filter or on a piece of cloth sometimes solves the problem. Another great [idea for a filter](#) comes from E.S. However, just filtering will not always remove all solid impurities. A common impurity that is hard to remove is suspended iron hydroxide, originating from corrosion of (stainless) steel cathodes. The fluffy, voluminous form of the material often gives it a white or yellowish foggy appearance. This is next to impossible to remove unless some sodium hydroxide or pool coagulant is added first. This causes the iron hydroxide particles to coagulate, making them easy to remove by filtration. Another possibility is to add hydrochloric acid to lower the pH to between 2 and 3. This will dissolve the iron hydroxide. If sodium hydroxide is then added to raise the pH to above 7 again, the iron hydroxide is precipitated in a more dense form which is easily removed by filtration, even with common filter paper.

In this step, the advantages of using sodium chloride will become evident. When potassium chloride is used instead potassium chlorate crystallises during operation of the cell due to its relatively low solubility. To separate the potassium chlorate from insoluble impurities the electrolyte has to be filtered hot. The solution usually takes quite a long time to pass through the filter and if it cools during this time, potassium chlorate will crystallise and block the filter. Alternative methods have been developed to separate potassium chlorate from insoluble impurities. For example, the solution may be boiled and sufficient water added to dissolve all potassium chlorate. If the solution is then allowed to cool slowly, crystals of potassium chlorate will form on the suspended insoluble impurities. These will sink to the bottom, usually leaving a clear solution. The clear solution is then carefully decanted and allowed to cool further. This

method will not remove the insoluble purities as well as filtering will but it is much less laborous.

Destruction of hypochlorite

Next, the electrolyte is boiled to decompose remaining hypochlorite. 15 minutes of vigorous boiling is sufficient. After that, the pH of the solution is checked and it is made slightly alkaline by adding sodium hydroxide solution. Bring the pH to between 8 and 9.

Metathesis reaction

At this point, a clear solution of sodium chlorate (with residual chloride) has been obtained. This can be used either to prepare potassium or barium chlorate (or other chlorates which are not further elaborated upon here), or it can be used to prepare perchlorates, described elsewhere.

Potassium chlorate is by far the most commonly used chlorate in pyrotechnics. For practical purposes, the preparation of this compound is discussed here. For the preparation of barium chlorate the amounts will have to be adjusted.

1. Weigh out either 127g of potassium chloride or 355g barium chloride for every 100 g of sodium chloride that was started with, depending on whether you want to prepare potassium or barium chlorate. Dissolve this in as little water as possible (dissolve in minimum amount of boiling hot water, add a bit more water and allow to cool. Nothing should precipitate. If it does, add some more water and heat again)
2. Add this solution to the electrolyte. A white precipitate of potassium or barium chlorate should form.
3. Bring the solution to a boil. Add 20 ml amounts of water to the solution in 5 minute intervals until all chlorate has dissolved. If all chlorate dissolves upon heating without the addition of extra water, allow the water to evaporate until a thin crust of chlorate forms on the surface (indicating that the saturation point has been reached). Then add 20 ml of water and boil for a minute to redissolve the crust.
4. Allow the solution to cool to room temperature. Potassium or barium chlorate will crystallise. If it has cooled to room temperature, cool further to 0 deg C.
5. Filter to obtain the crude chlorate crystals. Rinse them thoroughly with ice-cold water. The filtrate can be saved to prepare the next electrolyte, as is described in the section on recycling electrolyte.

2.11 Purifying the product

The crude product can be purified by recrystallisation. The low solubility of potassium chlorate makes this method very convenient to use and will greatly improve the purity with a relatively small loss of product. Barium chlorate is somewhat more soluble and to prevent losses it is a good idea to use the impure barium chlorate 'waste' from this procedure in the electrolyte of a new cell. Some treatment is necessary, which was described earlier. If a single recrystallisation step does not yield a sufficiently pure product, the method can be repeated to further increase the purity. Usually one or two recrystallisations will yield a product that does not impart the characteristic yellow color of sodium impurities to a flame.

1. Place the crude product in a pan and add 100 ml of water for every 35g of crude potassium chlorate or 50g of barium chlorate. Bring this to a boil.
2. Add 20 ml amounts of water to the boiling solution until all the chlorate has dissolved.
3. Check the pH of the boiling solution. It should be neutral or slightly alkaline. If it is acidic, add potassium hydroxide

solution until it is slightly alkaline (pH 7.8) again. If this is not done, traces of acid may be included in the product making it very dangerous to use in pyrotechnic compositions.

4. Allow the solution to cool to room temperature. The chlorate will crystallise.
5. Filter and rinse the crystals in the filter well with ice cold water. The filtrate may be used to prepare the electrolyte for a new cell, as was described in the section on recycling old electrolyte.
6. The crystals may be dried in an oven at 100 deg C.

Thermal decomposition of hypochlorites

This is an alternative method of chlorate manufacture. It is more laborous than the electrolytic method, and can only be used for small batches at a time. The starting materials are quite easily available however as bleach and pool chlorinating agents and it only requires the use of simple tools.

3.1 Starting materials

Possible starting materials are sodium hypochlorite and calcium hypochlorite. The former is available in solution as bleach and antifungal spray for bathrooms. Calcium hypochlorite finds use as a chlorinating agent for pools. However, different varieties exist. Carefully read the package to make sure you have the right material. It usually states a '85% available chlorine' content for calcium hypochlorite. A higher available chlorine content may mean it is something else, most likely trichlorohydrocyanuric acid.

3.2 Method

Depending on the starting material, sodium or calcium hypochlorite, a different procedure must be followed. Each is described separately below.

Procedure when using sodium hypochlorite

It is assumed bleach will be used, which is usually a 4% solution of sodium hypochlorite in water. If a less or more concentrated solution is used, adjust the amounts accordingly.

1. Take 1 liter of bleach, and place this in heat resistant glass or stainless steel container. Bring it to a boil.
2. Boil the solution until only about 140 ml of solution is left. The exact volume is not critical, a deviation of 10 to 20 ml is acceptable.
3. Allow the solution to cool. If crystals form upon cooling, filter the solution after it has completely cooled. The crystals are sodium chloride and can be discarded.
4. In a separate container, prepare a solution of potassium chloride. Dissolve 28 grams of potassium chloride in the smallest volume of water possible (about 80 ml). This can be done by dissolving the potassium chloride in about 90 ml of boiling water, and allowing it to cool. If crystals form, add some more water, boil again to dissolve the potassium chloride, and allow to cool again. If crystals form, repeat. If not, the solution is ready to use.
5. Mix the boiled bleach solution with the potassium chloride solution. A white precipitate should form. This is potassium chlorate.

6. Bring the solution to a boil and add water until all potassium chlorate has dissolved.
7. Allow the solution to cool slowly. Crystals of potassium chlorate will form. Cool the solution to 0 deg C.
8. Filter to obtain the raw potassium chlorate. Rinse the crystals in the filter with ice-cold water. The product can be further purified as described below.

Procedure when using calcium hypochlorite

warning: On one occasion a small explosion occurred when I was doing this preparation. I am not sure exactly what caused the explosion. It seems to have been a steam explosion. I was also not sure whether I was using calcium hypochlorite or trichlorohydrocyanuric acid, another common pool chlorinating agent. It seems to be very uncommon that explosions happen and they can probably be prevented by vigorous stirring, but I thought everyone attempting this method should know so proper precautions can be taken. The procedure below has been optimised to reduce the chances of an explosion happening.

1. Place 250 ml of water in a heat resistant glass or stainless steel container, large enough to hold twice that volume.
2. Bring the water to a boil.
3. To the boiling water, add 125 gram of calcium hypochlorite in 10 gram portions. The calcium hypochlorite usually comes in tablets, which need to be crushed first. Stir vigorously during this step, occasionally scraping over the bottom to prevent the formation of a cake of calcium chloride. The solution will foam a lot. If too much foam is developed, do not add any more calcium hypochlorite and boil until the foam subsides. Then continue adding calcium hypochlorite.
4. When all calcium hypochlorite has been added, continue boiling until no more foaming is observed. Stir continuously.
5. Allow the solution to cool down, and filter to remove the precipitated calcium chloride.
6. In a separate container, dissolve 68 grams of potassium chloride in the smallest volume of water possible (approximately 195 ml). This can be done by dissolving the potassium chloride in about 200 ml of water, and allowing it to cool. If crystals form, add some more water, boil again to dissolve the potassium chloride, and allow to cool again. If crystals form, repeat. If not, the solution is ready to use.
7. Mix this solution with the boiled calcium hypochlorite solution. A white precipitate of potassium chlorate should form.
8. Bring the solution to a boil and add water until all potassium chlorate has dissolved.
9. Allow the solution to cool slowly. Crystals of potassium chlorate will form. Cool to 0 deg C.
10. Filter to obtain the raw potassium chlorate. Rinse the crystals in the filter with ice-cold water. The product can be further purified as described below.

3.3 Purifying the product

The product can be purified by recrystallisation, just like the product of the electrolytic procedure. For convenience, the same procedure is given again here:

1. Place the crude product in a pan and add 100 ml of water for every 20 g of crude product. Bring this to a boil.

2. Add 20 ml amounts of water to the boiling solution until all the potassium chlorate has dissolved.
3. Check the pH of the boiling solution. It should be neutral or slightly alkaline. If it is acidic, add potassium hydroxide solution until it is slightly alkaline (pH 7..8) again. If this is not done, traces of acid may be included in the product making it very dangerous to use in pyrotechnic compositions.
4. Allow the solution to cool to room temperature. Potassium chlorate will crystallise.
5. Filter and rinse the crystals well with ice cold water. The filtrate may be discarded or concentrated by evaporation and the residue added to the electrolyte for a next batch.
6. The crystals may be dried in an oven at 100 deg C.

Chapter 4: Literature

The amount of literature available is overwhelming. A short list of interesting reading material follows.

1. F Hine, "Electrode processes and electrochemical engineering", Plenum Press, New York (1985)
2. F. Foerster and E. Muller, Z. Elektrochem, **8**, 8, 515, 633, 923 (1902); **9** 171 (1903); **10**, 781 (1904).
3. [Webpage of Mike Brown](#)

This list is under construction

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Chapter 1: Introduction

Industrially, perchlorates are exclusively prepared by the electrochemical method. In the past, thermal decomposition of chlorate has been used but since this process is very inefficient it has been abandoned long ago. Chemical oxidation of chlorates is currently not very economical either, but it may become an option in the future. For amateur pyros, each of these methods may be used as we need not be concerned with the economy of the process as much as commercial operations do. The electrochemical method is convenient to use if you have a chlorate cell with the right anodes already, since then making perchlorates is simply a matter of operating the cell for a bit longer. If you can get chlorates in quantity for cheap, for example as a herbicide, the thermal decomposition method is an option. The method is quick, and requires no chemicals other than the chlorate starting material. Perchlorates can also be prepared by chemical oxidation of chlorates. The required chemicals are relatively expensive, but the method is quick and simple.

Chapter 2: Electrolytic preparation

Chlorates can be oxidised in an electrochemical cell to yield perchlorates. The preferred starting material for this method is sodium chlorate, since it is very soluble. Potassium chlorate is seldom used due to its low solubility, and ammonium chlorate should never be used since it leads to the formation of sensitive and explosive NCl_3 in the cell. Sodium perchlorate is conveniently converted in high yield to a number of other perchlorates (such as potassium and ammonium perchlorate) by double decomposition (metathesis) reactions. It is assumed from here on that sodium chlorate is used as starting material.

Cell construction

Electrochemical cells for perchlorate synthesis do not differ much from chlorate cells. The most important difference lies in the anode material. Not all anode materials suitable for chlorate synthesis can also be used for perchlorate synthesis. Most cell body materials used in chlorate cells may also be used in perchlorate cells. The effect of temperature and pH deviating from the optimal values is of much less importance in perchlorate cells. Finally, the voltage at which perchlorate cells operate is somewhat higher because the potential at which the conversion reactions take place is higher. The general structure of both cell types is the same: two working electrodes, and no diaphragm.

Electrode materials

Like in chlorate cells, stainless steel is a suitable cathode material. Mild steel may also be used. While copper and brass will also work, they may cause problems with copper contamination when they erode.

Anode materials for perchlorate cells should have a high oxygen overpotential. What exactly that means is not further discussed here; it suffices to say that if the oxygen overpotential at a certain anode material is not high enough oxygen will be evolved instead of chlorate oxidised to perchlorate. No perchlorate will be formed, and the anode material is usually attacked comparatively quickly. This holds also for chlorate cells, but the problem is less severe there since lower potentials are involved. Anode materials suitable for perchlorate synthesis are listed below. These are also described in the chlorate synthesis section but are repeated here for convenience.

Platinum: The obvious disadvantage of platinum is its high price. However, it corrodes only at a very slow rate and therefore provides an almost ideal anode material. High efficiency can be reached with platinum and processing of the electrolyte is greatly simplified due to the absence of insoluble anode erosion products.

Lead dioxide: Lead dioxide provides an economical alternative to platinum. Efficiency of lead dioxide anode based cells is usually slightly lower than that of platinum based cells, but the difference is small. Lead dioxide anodes are not easily bought and must be made. This takes some work and effort, but the anodes are cheap, fairly resistant to corrosion even at higher temperatures. More information on [lead dioxide anodes](#) of several types is given elsewhere on this homepage.

DSA: DSA stands for Dimensionally Stable Anode. This is the common term used to refer to anodes consisting of a layer of noble metal oxides (usually RuO_2 and TiO_2) coated onto a substrate, usually titanium. This type of anode is finding increased use in industrial cells because of its comparatively low cost when compared to platinum and its resistance to corrosion. The chemicals required to manufacture these anodes are expensive and difficult to handle. However, if the chemicals can be obtained and suitable equipment is available, the procedure to make the anode seems fairly straightforward and may be an option. For the preparation of these, the reader is referenced to the literature. Again, I'd be most interested in anyone's experiences with this type of anode.

Magnetite: This material has found use in industry in the past, but is rarely used nowadays due to its relatively high corrosion rate and low efficiency for perchlorate manufacture. The anodes are made by melting and casting $\text{FeO} \cdot \text{Fe}_2\text{O}_3$ into the required anode shapes. I have little literature available on this material, so it is not further discussed here.

Preparing the electrolyte

Sodium perchlorate can be made directly from sodium chloride by electrolysis in which case no special electrolyte for the chlorate to perchlorate step has to be prepared. The preparation of a chloride electrolyte is described in the text on chlorates.

A cell can also be operated purely for the chlorate to perchlorate conversion. An electrolyte has to be prepared before each batch in this case. If the cell has been operated before, it is best to 'recycle' the old electrolyte and all the impure fractions obtained during extraction and purification of the product. That way no product is wasted. When the cell is operated for the first time, a fresh electrolyte has to be prepared which can be done as follows.

Preparing fresh electrolyte

1. Prepare a saturated solution of sodium chlorate. Take about 60 grams of sodium chlorate for every 100 ml of solution and bring the solution to a boil. Then allow to cool to room temperature again. Sodium chlorate will crystallise as the solution cools. The solution is then filtered to obtain a clear saturated solution.
2. Optionally, 2 to 4 g/l of potassium dichromate, potassium chromate, sodium chromate or sodium dichromate may be added to improve efficiency. These compounds are suspected carcinogens, so if you choose to add any, know the

hazards involved and act accordingly. If lead dioxide anodes are used, do not add potassium dichromate as it will only reduce efficiency. Instead, 2 to 4 g/l of sodium or potassium fluoride may be used. Although not carcinogenic, the fluorides are nasty compounds as well and should be handled properly.

Recycling old electrolyte

1. If the electrolyte is not clear but contains suspended particles, remove these by filtration.
2. Dissolve any impure material left over from purification steps.
3. Re-saturate the solution with sodium chlorate, following the same procedure as described in step 1 of 'preparing a fresh electrolyte'.
4. Like described in step 2 of 'preparing a fresh electrolyte' you may now add dichromates, chromates or fluorides if you choose to do so.

Operating the cell

Perchlorate cells are operated at a higher voltage than chlorate cells and temperature and pH do not need to be controlled within strict limits for optimal efficiency. Other than that, operation is much like that of chlorate cells.

Like explained in the theory section on chlorate cells, the voltage over a cell may fluctuate if the current is kept constant. In typical chlorate cells this results in a cell voltage of 3 to 4 volts, whereas in perchlorate cells the voltage is higher, 5 to 7 volts usually. The current is kept constant at an acceptable level with respect to anode erosion. A maximum current per volume as exists in chlorate cells does not exist in perchlorate cells. The current could in theory be increased indefinitely to increase the reaction rate, were it not that anode erosion increases with increasing current density (the current per unit of anode surface area). The current is therefore usually set by the surface area of the anode. As a rule of thumb maintain a current density of 200 mA/cm².

The influence of cell temperature is two-fold: anode erosion increases with increasing cell temperature and the cell voltage is reduced at higher temperatures. The former is obviously unwanted, while a lower cell voltage means energy is saved. In industry the temperature is ofcourse chosen to get the best of both worlds, depending on what is more expensive: energy or anodes. We need not be concerned with economy as industry does so the temperature does not matter a lot. Try to keep it between 40 and 80 deg C. When using lead dioxide anodes, it is probably best to prevent the temperature from going very high. It can make the lead dioxide crack.

Finally, some water should be added from time to time to make up for what has evaporated. Try to maintain a constant electrolyte volume.

Running times

The required time to operate a cell depends on the current. The higher the current, the less time needed. In fact, the current is a measure of the reaction rate. Therefore, the amount of electricity that went through a cell is calculated by multiplying the current going through the cell (in amperes) by the time it has been flowing (in hours). The resulting number is measured in amperage-hours (abbreviated as Ah). To convert 100 grams of sodium to sodium perchlorate 50 Ah are required if the cell operates at 100% efficiency. In real life a cell will never reach 100% efficiency, and more electricity is needed.

Example: A 200 ml cell contains initially about 100 grams of sodium chlorate (the solubility of NaClO₃ in water is about 50 g/100ml at room temperature). Per 100 grams, 50 Ah are needed. So, if a cell operates at a current of 2 amperes, it would take $50/2 = 25$ hours to convert all chlorate to perchlorate in a cell operating at 100% efficiency. If the cell actually operates at 80% efficiency, $100/80 * 25 = 31.25$ hours (or 31 hours, 15 minutes) are needed.

If perchlorate is prepared by continuing to run a chlorate cell after all chloride has been consumed, the total run time is ofcourse the sum of the time required for the chloride to chlorate conversion and the chlorate to perchlorate conversion.

Processing the electrolyte

When done, raw potassium perchlorate or ammonium perchlorate may be prepared from the electrolyte as follows:

Filtering

The first step is filtration. The electrolyte usually contains suspended solid particles. These consist of erosion products of the anodes, the cell walls, and the unsubmerged parts of the cathodes. These particles may be very small and are not always easily removed with common filtering paper. Filtering through a layer of diatomeous earth (sold in shops for aquarium supplies) in a filter or on a piece of cloth sometimes solves the problem. However, even that will not always remove all solid impurities. A common impurity that is hard to remove is suspended iron hydroxide, originating from corrosion of (stainless) steel cathodes. The fluffy, voluminous form of the material often gives it a white or yellowish foggy appearance. This is next to impossible to remove unless some sodium hydroxide or pool coagulant is added first. This causes the iron hydroxide particles to coagulate, making them easy to remove by filtration. Another possibility is to add hydrochloric acid to lower the pH to between 2 and 3. This will dissolve the iron hydroxide. If sodium hydroxide is then added to raise the pH to above 7 again, the iron hydroxide is precipitated in a more dense form which is easily removed by filtration, even with common filter paper.

Chromate and dichromate removal

If chromates or dichromates were used to increase the cells efficiency they should now be removed. Adding a solution of barium chloride to the electrolyte will precipitate any chromate or dichromate as the corresponding barium compounds. Add small amounts of a 10% barium chloride solution to the electrolyte. A yellow precipitate will form. If no more yellow precipitate is formed, filter to remove the barium compounds. A white (sometimes clearly crystalline) precipitate may form instead of a yellow precipitate. This is barium chlorate or perchlorate. If this happens, do not add any more barium chloride solution and filter to remove the precipitate.

Destruction of chlorate

The next step is the destruction of residual chlorate. Even when a cell is operated for many times the required running time, some chlorate is still present in the electrolyte. Since chlorates and perchlorates behave very differently in pyrotechnic compositions (see the [safety](#) page among others) chlorate contamination can be very dangerous. If the cell is not operated long enough to convert most of the chlorate to perchlorate the chlorate contamination may be very severe and it is unpractical and very inefficient to attempt to destroy it all. If this is the case I suggest tthis step is skipped, and the raw product is extracted. Ammonium perchlorate cannot be made this way, as it would result in the formation of the dangerously unstable explosive compound ammonium chlorate (also see the [safety](#) page). Conversion to potassium perchlorate may however be tried. This will ofcourse afford a heavily chlorate contaminated batch of perchlorate, probably even something that can better be considered to be a chlorate/perchlorate mixture or perchlorate contaminated chlorate. This material could be used to an extremely limited extend in pyrotechnic compositions when it is treated as a chlorate, or, a better option, it can be used as a starting material for the thermal decomposition or chemical oxidation preparations of potassium perchlorate described later.

Residual chlorate is usually destroyed by the action of reducing agents. Sodium sulfite is used for this purpose in industrial setups. Iron(II)sulfate is another option, and the chemical can be bought in some gardening supply shops as it is used to supply plants with iron. A third method destroys chlorates by the action of strong acids. The cell electrolyte is acidified with hydrochloric acid to a pH of 1 to 2, and the solution is boiled. Chlorates will decompose and yield a yellow gas, chlorine dioxide. The gas will partially dissolve in the solution, imparting a bright yellow color to it. In

high concentrations chlorine dioxide is dangerously explosive and sensitive but if done using proper ventilation the small amounts evolved in this reaction are very unlikely to cause dangerous levels. The gas is however quite toxic and inhalation should be avoided at all times. Never do this step inside unless a well functioning fumehood can be used. After boiling for 15 minutes raise the pH to around 8 or 9 again using sodium hydroxide. This should afford a colorless solution. A qualitative test for chlorate should now be performed to make sure all chlorate has properly been destroyed. Such tests are described on the [product analysis](#) page.

If any other method is used to destroy residual chlorate the pH must always be adjusted afterwards to slightly above 7. Otherwise, traces of acid may be incorporated into the product in later steps which can make it very dangerous to use in pyrotechnic compositions.

Double decomposition

A decision will have to be made at this point whether the intended product is ammonium or potassium perchlorate. Other perchlorates can be made as well but are not discussed here as they find very little use in pyrotechnics.

If residual chlorate was not destroyed the choice is simple since ammonium perchlorate is not an option. Ammonium chlorate could be formed in the process which is, as mentioned several times already, a dangerously unstable explosive compound the formation of which should at all times be avoided (even in trace amounts). If chlorate was properly destroyed, and a qualitative test indicates so, ammonium perchlorate may be prepared. **1.** If potassium perchlorate is the intended product, take 70 grams of potassium chloride for every 100 grams of sodium chlorate that was started with and dissolve this in the smallest volume of water possible. If instead ammonium perchlorate is required, take 50 grams of ammonium chloride and dissolve in the smallest volume of water possible.

2. Mix this solution of either potassium or ammonium chloride with the electrolyte. A white precipitate of the corresponding perchlorate should form.

3. Boil the solution and add small amounts of water until all the perchlorate has dissolved. Due to the low solubility of potassium perchlorate a large volume of water may be needed then. If a sufficiently large container is not available the solution may be split up in several portions that are later recombined.

4. When all has dissolved, check the pH of the solution. It should be neutral or slightly alkaline (above 7). If it is not, add some dilute sodium hydroxide solution to increase the pH to between 7 and 8. When this value is overshoot, hydrochloric acid may be used to lower the pH again.

5. Allow the solution to cool slowly to room temperature. The perchlorate will crystallise during this. Cool the solution further to 0 deg C, and filter. Rinse the crystals in the filter with some ice-cold water. This raw product may be further purified as described below.

Purification

The product can be purified by recrystallisation. This method is especially suitable for potassium perchlorate due to its low solubility. Little product will be lost, and the purity is greatly increased. Ammonium perchlorate suffers slightly worse losses when recrystallised, but still acceptable. The impure ammonium perchlorate should be discarded since recycling could result in NCl_3 formation in the cells. The losses occurring when potassium perchlorate is recrystallised are so slight recycling is hardly worth the effort (a liter of recrystallisation solution contains only a few grams of perchlorate). Recrystallising is done as follows:

1. Place the crude product in a pan and add 100 ml of water for every 20 g of raw potassium perchlorate, or 100 ml of water for every 50 gram of raw ammonium perchlorate. Bring this to a boil.

2. After it has boiled for a few minutes, add 10 ml amounts of water to the boiling solution in 5 minute intervals until

all the product has dissolved.

3. Check the pH of the boiling solution. It should be neutral or slightly alkaline. If it is acidic, add potassium hydroxide solution until it is slightly alkaline (pH=7...8) again. If ammonium perchlorate is the intended product, use ammonia instead. If this is not done, traces of acid may be included in the final product making it very dangerous to use in pyrotechnic compositions.

4. Allow the solution to cool to room temperature. The purified product will crystallise.

5. Filter and rinse the crystals well with ice cold water. The filtrate should be discarded

6. The crystals may be dried in an oven at 100 deg C.

Chapter 3: Preparation by thermal decomposition of chlorate

Chlorates are thermodynamically unstable. Over time they will decompose into a mixture of chlorides and perchlorates. In essence, the chlorate will undergo a redox reaction with itself (a so-called auto-oxidation reaction). Due to the kinetic stability of chlorates however, the process is slow at room temperature. A well known example of the same phenomenon is diamond: Diamonds are unstable at common pressures and temperatures. They turn into graphite extremely slowly. If a diamond is heated, the process is sped up. Similarly, if chlorates are heated the reaction rate is increased enough for it to be used as reaction pathway in the preparation of perchlorates. When potassium chlorate is used, the resulting perchlorate is easily separated from the chloride by recrystallisation. There may be several other chlorates that this method can be used with, but potassium chlorate seems to be the most well investigated option. In any case, ammonium perchlorate cannot be prepared directly with this method due to the explosive and instable nature of ammonium chlorate, as mentioned earlier. In the first large scale perchlorate plants this method was used to prepare potassium perchlorate. Ideally, this preparation is performed in an oven since it involves heating the chlorate for several hours. The chlorate used should be free of impurities that catalyse chlorate decomposition (such as most d-block metals). The following description assumes potassium chlorate will be used as a starting material.

1. Heat pure potassium chlorate to slightly over its melting point. A colorless clear liquid is obtained. Before heating make sure no organic material or other fuels are present in the chlorate or able to fall into the molten chlorate. This would result in a violent reaction. Do not overheat since this will decompose the chlorate, yielding chloride only.

2. Maintain this temperature for several hours. During this time the potassium chlorate will undergo the auto-oxidation reaction. Due to the higher melting point of potassium chloride and potassium perchlorate the melt will solidify slowly during this time. It becomes quite hard to judge the correct temperature as the melt solidifies, and if an oven is not used a thermometer is essential to judge the correct temperature. Too high a temperature will cause the perchlorate to decompose, a low temperature will result in incomplete conversion.

3. After the mixture has completely solidified, allow it to cool to room temperature. Test a sample of the cooled residue for chlorate, as described in the [analysis](#) page. If chlorate is present it needs to be destroyed before extraction of the perchlorate. [Destruction of chlorate](#) is described earlier in this text, in the section dealing with processing the electrolyte from the electrolytic preparation of perchlorates.

4. [Recrystallise](#) the residue, as described earlier. Two recrystallisation steps are sometimes needed to separate the potassium perchlorate completely from the chloride as there is quite a lot present.

Chapter 4: Preparation by chemical oxidation

A third method to convert chlorates to perchlorates is by chemical oxidation. A sufficiently strong oxidiser added to a

chlorate can oxidise a chlorate to a perchlorate. Suitable oxidisers are persulfates and lead dioxide in concentrated sulfuric acid. Hydrogen peroxide does not seem to work. I must admit my experience with this method is limited and I have not been able to obtain much literature about it. It is mentioned in literature however, and it is definitely a possible method that can be used with good results. If anyone has some experience with it, I would be most interested to hear about it. The experiments I have conducted involved sodium persulfate as the oxidiser. I will give an account of the general method I used, the ideas behind it and the results obtained with it. Anyone with comments, results, ideas, anything is very welcome to comment on it. I can currently not do any further experiments until July/August this year. Soon after that, this text should be updated. If you wish to try this method in the meantime this may be used as a starting point:

Theory

Persulfates are strong oxidisers. They are reduced according to the following half-reaction:

[REACTION]

The H^+ generated in this reaction will prevent it from taking place below a certain pH. When a base is added to neutralise the acid generated the reaction may go to completion. All persulfate may be consumed in the reaction. Persulfate being a stronger oxidiser than perchlorate may be used to convert chlorates to perchlorates according to the following half reaction:

[REACTION]

Neither persulfates, chlorates or perchlorates are destroyed at a significant rate at the temperature of boiling water, so the reaction rate may be increased by boiling a solution containing the reactants.

Oxidation of $KClO_3$ by persulfate

The general procedure I tried:

A solution of 30 g/l sodium persulfate was prepared and the pH raised to 14 by the addition of a concentrated sodium hydroxide solution. The sodium persulfate was obtained from an electronics supply store, where it was sold for etching printed circuit boards. A foggy solution was obtained, which was filtered. 5 ml of the clear solution obtained after filtering was added to a test tube. Approximately 1 gram of potassium chlorate was added to the same tube, and solution heated. The solution was boiled vigorously for 15 minutes during which time water was added occasionally to make up for what had evaporated. The solution was then allowed to cool. Upon cooling white crystals formed. These were filtered, washed with ice cold water and recrystallised. The crystal shape during recrystallisation was observed and found to resemble that of potassium perchlorate best. As described in the [analysis](#) page, crystal shape is not a reliable way to determine the identity of a product however. The crystals obtained after recrystallisation were tested qualitatively for chlorate with phenylanthranilic acid (as described in the [analysis](#) page). Chlorate was shown to be present. It seems most likely that the chlorate was only partially converted to perchlorate. Maybe the addition of more persulfate or allowing a longer reaction time will convert more chlorate to perchlorate. Destruction of the chlorate followed by recrystallisation should afford a chlorate free product.

Chapter 5: Literature

1. Schumacher, J.C., "Perchlorates", New York, Reinhold Publishing Corp., 1960
2. Remy, H. "Treatise on Inorganic Chemistry", New York, Elsevier Publishing Co., 1956
3. [Mike Brown's homepage](#)

list under construction

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Analysis of products

When preparing chemicals for pyrotechnics compositions at home, it is important to confirm the identity and purity of the products. When impure chemicals are used the risk of accidents is greatly increased. Especially in the preparation of chlorates and perchlorates the risk is severe. The properties of each chemical in pyrotechnic compositions are very different, and very sensitive or unstable compositions may result from mistaking chlorate for perchlorates, or of not appreciating the risk of chlorate contamination sufficiently. Therefore, the identity and purity of the products should be determined. Also, in the process of preparing chlorates it is often useful to know the chloride content of a solution. Several methods that may be used to determine the composition of chloride/chlorate/perchlorate mixtures are described on this page. It will be assumed that the reader is familiar with common analytical chemistry techniques, such as pipetting and titrating. These can be found in many textbooks.

1. [qualitative test for chlorate](#)
2. [qualitative test for chloride](#)
3. [titration to determine chloride content](#)
4. [titration to determine chlorate content](#)
5. [gravimetric determination of chlorate](#)
6. [rough gravimetric determination of oxygen content](#)
7. [crystal shapes](#)

Qualitative test for chlorate

Very often it is convenient to determine whether a chlorate is present in a mixture or chemical. The possibility of chlorate contamination of homemade perchlorate is inherent to the process, and a test for the presence of chlorate is then essential. Two methods to determine the presence of chlorate will be described. The first, a colorimetric test, is very sensitive, quick and simple. Unfortunately it requires the use of a chemical that can probably only be obtained from chemical suppliers. The second test is very insensitive. It will only indicate a potassium chlorate contamination worse than 20% by mass of potassium perchlorate. It may be used to distinguish between chlorate and perchlorate, but not to determine whether your homemade perchlorate is pure enough to be handled as pure perchlorate.

Colorimetric test for chlorate

This test will indicate the presence of very slight chlorate contamination. It is convenient for testing pyrotechnic mixtures since nitrate, chloride, nor perchlorate will disturb the test.

1. Take approximately 100 mg of phenylanthranilic acid, and put this in a test tube.
2. Add 0.5 ml of concentrated sulphuric acid and shake to dissolve the phenylanthranilic acid. This usually takes a few minutes.
3. Place a 500 mg sample of the material to be tested in a test tube and add 2 ml of water. Shake well to dissolve all chlorate possibly present. Filter if insoluble purities are present.
4. To this sample solution, add a few drops of the phenylanthranilic acid solution. An orange or red color indicates presence of chlorate. A solution of pure perchlorate or chloride merely gives a white precipitate.

'Acid sensitivity' test for chlorate

This test is very insensitive but may be used to distinguish chlorate from perchlorate or indicate very heavy contamination of a perchlorate with chlorate. It relies on the fact that chlorate/sugar mixtures ignite when they contact sulfuric acid.

1. Take some sample material and make this into a fine powder with a mortar and pestle.
2. Clean the mortar and pestle well with hot water, dry it well, and then grind up some common table sugar.
3. Take 500 mg of the powdered sample and 500 mg of the powdered sugar. Mix these carefully using the [diapering method](#)
4. Place this mixture on a tile outside and drop a drop of concentrated sulphuric acid on it. If the mixture contains more than 20% chlorate it will ignite.

Qualitative test for chloride

When in the process of purifying chlorates, it is quite useful to determine whether the chlorate has been successfully separated from chlorides or not. Though chloride contamination is usually not very dangerous for pyrotechnic purposes, it will disturb flame colors and increase hygroscopicity of a mixture. The following test will indicate chloride contamination.

1. Take 100 mg of sample material and add 2 ml of water. Shake to dissolve any chloride possibly present. If necessary, filter to remove insoluble impurities.
2. Add a few drops of 10% (w/v) silver nitrate solution. If chloride is present, a white precipitate will form.

Titration to determine chloride content

When using the electrolytic procedure to prepare chlorates, this method may be used to determine the amount of chloride still present in the electrolyte. It requires some tools and chemicals not every amateur pyro will have. It is probably not possible to do this accurately using improvised equipment.

1. First, prepare a silver nitrate solution. Dry some finely powdered analytical grade silver nitrate at 120 deg C for 2 hours and allow it to cool in a covered vessel in a desiccator. Accurately weigh about 8.5 g, dissolve it in water and make up to 500 ml in a graduated flask. Calculate the molarity from the weight of silver nitrate employed. If 'pure recrystallised' silver nitrate is used instead of analytical grade, the solution should be standardised against sodium chloride before use, using the procedure outline below. Solutions of silver nitrate should be protected from light and are best stored in amber-colored glass bottles.
2. Then, prepare an indicator solution by dissolving 5g potassium dichromate in 100 ml of water. Alternatively, and preferably, dissolve 4.2g potassium chromate and 0.7g potassium dichromate in 100 ml of water.
3. Pipette a sample of such volume as contains approximately 0.025 moles of chloride into a 250 ml conical flask resting on a sheet of white paper. Dilute to approximately 25 ml.
4. Add 1 ml indicator solution (preferably with a pipette).
5. Now, slowly add silver nitrate solution from a burette, swirling the flask constantly until the red color formed by the addition of each drop begins to disappear more slowly: This is an indication that most of the chloride has been precipitated.
6. Continue the addition dropwise until a faint but distinct change in color occurs. this **faint** reddish-brown color should persist after brisk shaking.

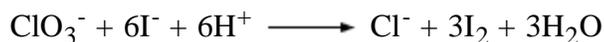
- Determine the indicator blank correction by adding 1 ml of the indicator solution to a volume of water equal to the final volume in the titration and then 0.01M silver nitrate solution until the color of the blank matches that of the solution titrated. The indicator blank correction, which should not amount to more than 0.03 - 0.10 ml of silver nitrate, is deducted from the volume of silver nitrate used in the titration.
- Repeat the titration two more times and average the results. The titrations should agree within 0.1 ml.

Titration to determine chlorate content

Trace amounts cannot be detected with this method, but it is very convenient to determine the chlorate content of the electrolyte in chlorate or perchlorate cells during operation. Two procedures are described below. Both work well. The sample solution must be free of hypochlorite. This can be accomplished by reducing the hypochlorite by addition of an excess of oxalic acid, followed by titration with potassium permanganate in the usual manner.

Iodometrically

- Treat the sample to remove hypochlorite, and dilute it such as to obtain a solution containing approximately 0.02M of chlorate.
- Place 25 ml of the chlorate solution in a glass-stoppered conical flask and add 3 ml of concentrated hydrochloric acid followed by two portions of about 0.3g each of pure sodium hydrogencarbonate to remove air.
- Add immediately about 1.0 g of iodate-free potassium iodide and 22 ml of concentrated hydrochloric acid.
- Stopper the flask, shake the contents, and allow it to stand for 5-10 minutes. Iodine is liberated according to the following reaction:



- Titrate the solution with standard 0.1M thiosulphate in the usual manner.

Using ferrous sulphate

- Treat the sample to remove hypochlorite, and dilute it such as to obtain a solution containing approximately 0.02M of chlorate.
- Place 25.0 ml of the sample solution in a 250 ml conical flask.
- Add 25.0 ml of 0.2M ammonium iron(II)sulphate solution (Mohr's salt) in 2M sulphuric acid.
- Cautiously add 12 ml of concentrated sulphuric acid.
- Heat the mixture to boiling, and cool to room temperature by placing the flask in running tap water.
- Now, either titrate the excess of Fe^{2+} with potassium permanganate or with 0.02M potassium dichromate with an indicator of 20 ml 1:1 water/phosphoric(V) acid and 0.5 ml sodium diphenyl-amine-sulphonate.

Gravimetric determination of chlorate

Trace amounts cannot be detected with this method, but it is very convenient to determine the chlorate content of the electrolyte in chlorate or perchlorate cells during operation. Burettes are not required, nor are carefully prepared standardised solutions. An accurate scale is however.

1. Boil the sample for 15 minutes to destroy remaining hypochlorite.
2. Dilute the sample to obtain about 100 ml of a solution containing approximately 0.2g ClO₃.
3. Add 50 ml of a 10 per cent solution of crystallised iron(II)sulphate, heat with constant stirring to the boiling point and boil for 15 minutes.
4. Allow to cool, add nitric acid until the precipitated basic iron(III) salt is dissolved, precipitate the chloride by means of silver nitrate solution, and collect and weigh as AgCl after the usual treatment.

Rough gravimetric determination of oxygen content

This is a quick and simple method to determine the amount of oxygen present in a mixture of chlorides, chlorates and perchlorates. Mixtures of chlorides with chlorates or of chlorates with perchlorates are most commonly encountered. Of these mixtures, the ratio between the two compounds can be determined. It can be useful to analyse a cell electrolyte. An accurate scale is required for this method to work well.

1. Accurately weigh a test tube, and record the weight. This is M₁.
2. Place approximately 1 gram of finely powdered sample in the test tube.
3. Very gently heat the test tube at low heat to dry the sample. At regular intervals, weigh. If the weight no longer decreases the sample is dry.
4. Add approximately 100 mg of dry manganese dioxide, mix well, and weigh. Record the weight, this is M₂.
5. Now, strongly heat the sample. It will melt and decompose. After some time it will solidify. Then, heat more strongly. If perchlorates are present another decomposition reaction will take place just before red heat. Do not heat so strongly as to melt the glass tube. The decomposition will be complete before that.
6. Allow the tube to cool and record the weight. This is M₃.
7. The composition of the sample can be indicated by the formula KClO_x, x being the molar oxygen content. So, for chlorides x = 0, for chlorates x = 3 and for perchlorates x = 4. Values in between are mixtures (eg x = 3.5 indicates a 50:50 mixture of chlorate and perchlorate).

X can now be calculated using the following formula:

$$x = \frac{(M_3 - M_2) * M_y}{16 * (M_3 - M_1)}$$

Where M_y is the molar mass of the chloride. For example, if the sample consisted of potassium salts, M_y is the molar mass of potassium chloride, 74.6g.

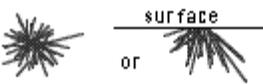
Crystal shapes

Another quick (but unreliable) way to distinguish between chlorates and perchlorates is by observing the crystals that

form upon recrystallisation. This is not a reliable method and only works if there is either a large fraction of chlorate in the mixture or if you know for sure you have either pure chlorate or perchlorate. In the latter case this can be used as a simple and reasonably reliable test to distinguish between the two compounds. The crystal shapes described below are valid only for potassium compounds and not for sodium or ammonium compounds.

Possible shapes

Crystals that form from KCl/KClO₃/KClO₄/NaCl/NaClO₃/NaClO₄/HCl mixtures in various compositions come in many different shapes. The most common shapes seen are these:

through a microscope	By the bare eye	crystal shape
		monoclinic
		monoclinic
		rhombic
		rhombic

The first crystal type, 'flat plates', is potassium chlorate, KClO₃. The crystals that form are very thin plates, almost square. They sometimes refract light in many colors since they are so thin initially (of the same order of magnitude as the wavelength of light). They are quite light and float in the solution and on its surface. When they grow larger they sink and stop refracting colored light.

The second crystal shape, sometimes described as 'cactus needles', is also potassium chlorate, KClO₃. It looks entirely different from the first shape, but the lattice structure is the same. The crystal shape is influenced by the presence of other species in the solution from which it crystallises (such as remaining unconverted chloride).

The third crystal shape is impure potassium perchlorate, KClO₄. It looks like needles, but the way they grow together is different from the cactus needles. They don't form clusters like the cactus needles and grow longer and thinner. Under a microscope you can clearly see they are rhombic. Pure potassium perchlorate looks different, and the difference is again caused by presence of impurities.

The fourth crystal shape is pure potassium perchlorate, KClO₄. When you crystallise a solution slowly enough fairly large crystals can form from the solution (up to 0.5 cm or so). These are clearly rhombic as can be seen with the bare eye. Under a microscope smaller crystals can be identified quite easily.

These conclusions were drawn after crystallising from solutions of every possible combination of the compounds mentioned above and are confirmed by powder X-ray diffraction analysis.

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Star pump

Under construction, sorry.

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Press

Pressing compositions (if done properly) is safer than ramming, since the process produces less shocks and friction and the operator can shield him/her self from the effects of accidental ignition. To consolidate more sensitive compositions such as whistle mix, pressing is the only safe method. Even though a lot can be achieved without the use of a press, eventually the lack of one will limit further progress. In this page the construction of a simple press is described.

Building a 5 ton press

The amount of pressure required to properly compress a powder into a solid mass without cracks depends on the surface area of the powder to be compressed (i.e. the inner diameter of the casing). Five tonnes should be enough for most projects, except maybe larger fountains or when compositions are used that are not easily compressed.

Materials

Hydraulic jack: An hydraulic jack is used to exert pressure. They can be found in the cars section of a hardware store. I have experimented with a 'scissors'-type jack as well, but found it not to work very well. It was permanently deformed after pressing only 10 rockets and most types cannot exert a force greater than 500 kg. The rockets were 2 cm ID blackpowder based rockets almost all of which exploded upon ignition, a sign of insufficient compression. Hydraulic jacks are available in different capacities. I use a jack of 5 ton capacity. The press described here should be able to withstand a force of at least 60 kN (a bit more than 6 tonnes). This takes into account that not the highest quality of materials is used.

Blast screen: Like mentioned, pressing causes less friction and shocks than ramming. However, compositions can ignite during pressing as well. The press provides extra confinement, and an explosion is very likely in that case. Even though this is not very common, it does happen and every possible precaution should be taken to protect yourself and surroundings from an accidental ignition. Therefore, a blast screen is absolutely essential. What the best material for such a screen might be is a point of discussion. I've heard of several people using polycarbonate (also called Lexan). This is a very strong 'shatterproof' ('shatter resistant' would be a better description) material. It is not cheap, but it is your safety that is at stake here. I personally think this is a good choice. Other people use thick sheets of plexiglas (acryl), but it is brittle and may shatter and produce shrapnell in the case of an explosion. 'Bulletproof glass' may also be an option if you can obtain it. I am not sure what it is made of but a friend uses it and it intuitively seems good. If it can stop a bullet, it should stop most shrapnell as well. A metal sheet may also provide some protection. Ofcourse, it is not transparent, but with the use of a mirror to view the object being pressed it may very well be a cheap and good solution. Mirrors can produce shrapnell when shattered by an explosion, but since the velocity of the shrapnell is likely to be smaller and directed away from the operator a thinner (and hence cheaper) transparent blast screen can be used to protect yourself from that. Also, the use of some of the thin plastic mirrors sold in camping stores instead of glass mirrors helps to reduce the danger. Pictures illustrating the principle will be given later.

Threaded steel rods Four steel threaded rods and 16 fitting nuts are needed. I used 10 mm diameter rods. Depending on the quality of steel this should allow a force of 60 kN (a bit over 6 tonnes) or more. If you intend to use a heavier press and exert more than that, larger diameter rods and/or a better grade of steel is needed.

Pipe To allow a plateau to slide over the threaded rods easily, they are surrounded with smooth pipe. Steel or PVC are easy to get, but just about anything will do as long as it fits the threaded rods.

Wood: Three pieces of wood of 4*25*25 cm are needed for the frame as well.

Assembly

1. Take all three pieces of wood and drill 11 mm holes on the corners of each, 4 cm away from the edges.

2. Insert a threaded rod through each hole of a piece of wood, and secure with two nuts.
 3. Slide a piece of pipe over each rod, and slide the second piece of wood onto the pipes.
 4. Screw a nut on every rod, slide the third piece of wood onto that and secure with the last four nuts.
3. Saw the blast screen to the appropriate size, drill six holes and screw it to the wood with heavy screws as indicated. In figure 5, a transparent blast screen is drawn. If a non-transparent material is used, such as wood or metal, a (preferably plastic) mirror can be used to watch the item being pressed as indicated in figure 6 (top view of the setup).
 4. Position the hydraulic jack in the center of the bottom piece of wood. Whatever is to be pressed is positioned on the sliding piece of wood and pressed against the top piece. If the pressure is exerted on a small area of wood (for example when a dowel is used), use a piece of metal sheet to protect the wood.

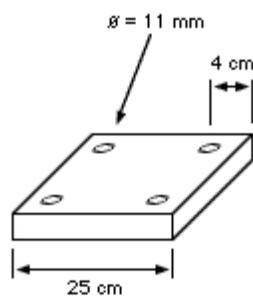


Figure 1

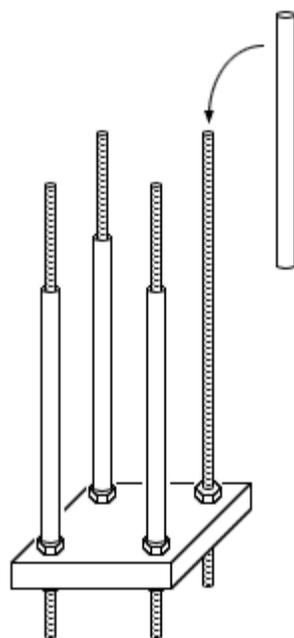


Figure 2

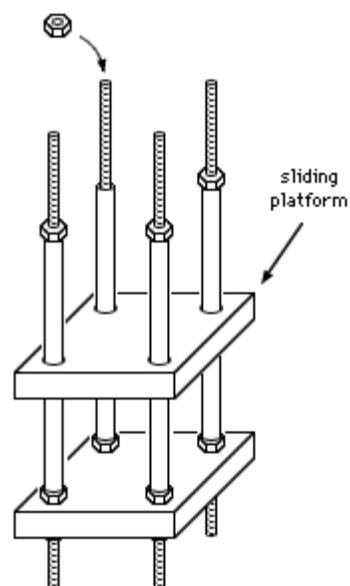
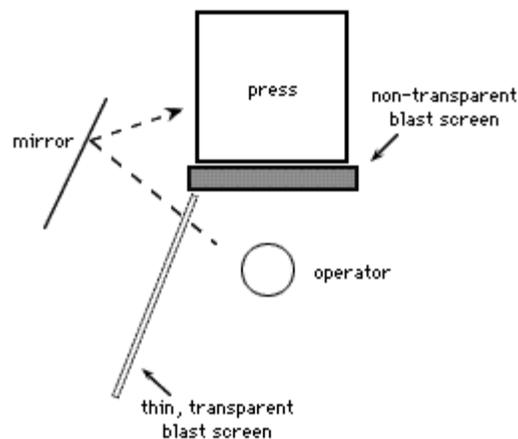


Figure 3



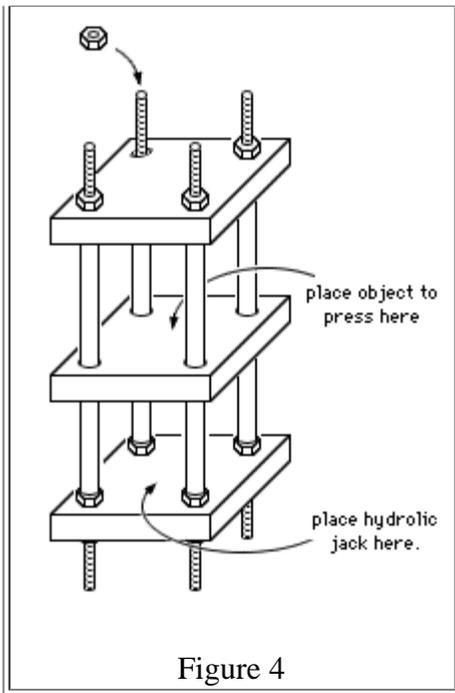


Figure 4

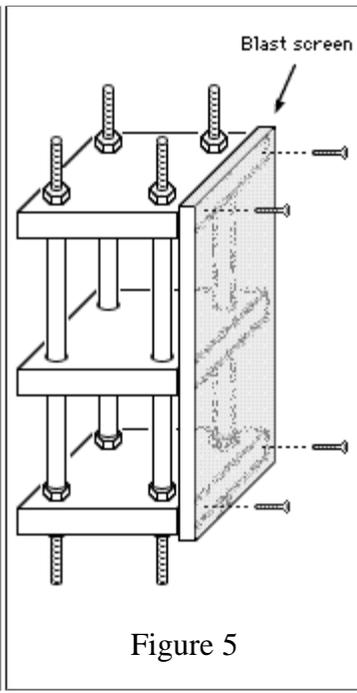


Figure 5

Figure 6

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Rocket tooling

While it is possible to build rockets without special tools, having a few tools makes it much easier to make reliable motors. Every type of rocket requires its own tooling, as the dimensions of each rocket are different. The tooling described here was designed for making [E6 rockets](#), but it can be scaled according to needs. The basic principle is the same for most rockets. A set of rocket tools usually consist of a number of rammers, a sleeve, and a spindle. Each of these is described below.

Rammers

A rammer consists of a hollow rod of aluminum, brass or wood that fits the rocket casing. The central hole accomodates the spindle. A set of rammers of different lengths is often used. As the casing is filled, shorter rammers are used. A rammer should be slightly smaller than the casing to allow it to slide easily and to provide an escape route for gasses in the case of spontaneous ignition during filling. The rammers for the E6 rocket described elsewhere on this page were constructed from a length of 12 mm aluminum rod which was filed to a diameter of 11 mm. A 3.5 mm lengthwise hole , 30 mm deep, was drilled to accomodate the spindle which is of 3 mm diameter.

Sleeve

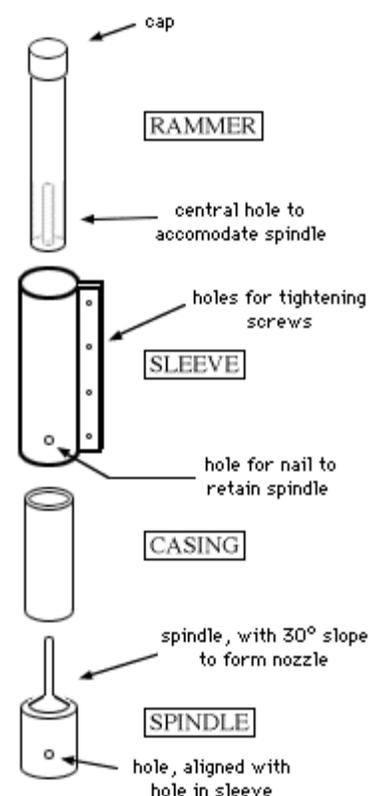
A sleeve tightly surrounds the casing to prevent it from splitting while it is being filled. It allows you to apply more force during filling, making it easier to sufficiently consolidate the propellant. Sleeves are best made from wood, brass or aluminum, but I personally use a PVC sleeve because it is easily constructed. PVC may cause some extra hazards due to static electricity buildup however. I would appreciate it if anyone can share experiences or insights in the static electricity problems associated with the use of PVC (or other plastics). A sleeve for E6 rockets was constructed from a piece of 25 mm inner diameter (32 mm outer diameter) standard PVC sewer pipe. A lengthwise slit is cut in a 10 cm length of such pipe, and the pipe is heated with a hair dryer to soften the plastic. While still hot, it is wrapped around a 16 mm rod and tightened in a vice to produce the shape indicated in the picture. After it has cooled, it is released from the vice and four 4 mm holes are drilled in the flat ends as indicated. Nuts and bolts are inserted in these holes to tighten the sleeve around the casing with. A 5 mm hole is drilled sideways into the sleeve as well, which can later be used to fix the spindle with a nail.

Casing

The casing should fit the sleeve tightly. It should not be possible to slide it out by hand after the screws have been tightened. If sliding occurs, glueing emory cloth to the inside of the sleeve can help.

Spindle

The spindle is conveniently constructed from a few centimeters of rod of a diameter equal to the outer diameter of the casings. If you have access to a lathe, you should have no problems constructing the spindle. It can also be done without the use of a lathe as follows. For the E6 rocket tools, cut 20 mm of an 18 mm diameter rod and fix it in a vise. Drill and tap a 3 mm hole in the center, about 10 mm into the piece. Then,



file the piece into the shape indicated in the picture. The casing can rest on the flat edges and the 30 degree slope will form the nozzle. Find a 37 mm long, 3 mm diameter aluminum rod and tap a 10 mm length to fit the hole in the base. Insert some epoxy glue into the tapped hole in the base and screw the rod in. It should extend 27 mm above the base and will form the core and nozzle opening. Finally, drill a 5 mm hole sideways through the base. Make sure it lines up with the hole in the sleeve when the spindle is slid into the sleeve. A nail can be inserted through this hole to fix the spindle in the sleeve.

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Fuse

Fuse comes in many varieties, fast, slow, hot, sparking, gas-generating, the list is endless. The types used most in pyrotechnics however are so called 'visco' fuse, 'black match', 'quick match' and timefuse. Below you will find a short description of each.

Visco

Visco is actually a brand name. It comes in two varieties, green and red. Red burns faster than green. The green variety is used often, and it burns at a rate of approximately a centimeter per second. It is water resistant for a limited period of time and once ignited will continue to burn when submerged. It also comes in two thicknesses. The thicker kind is about 2 mm in diameter.

Black match

Black match is very easily ignited and is therefore used commonly for 'priming'. For example, timefuse (see below) can be primed by drilling a hole through the side of the timefuse and inserting a piece of blackmatch, a practice called crossmatching. The blackmatch ignites reliably, igniting the timefuse in turn. It is not very suitable for providing delays as it is easily ignited from the sides by sparks. Since the fuse itself generates sparks it often skips sections of fuse when burning, making the delay very unreliable. Black match is also used to make 'quickmatch', described below. Black match can not be bought, but is easily made at home as follows:

1. Prepare some black powder. It need not be of very high quality. You can increase the charcoal content a bit to slow the burn rate. (this will also increase the number of sparks generated however). Mix this black powder with dextrin in a 9 to 1 ratio. Mix well, using the diapering or screening method (see [mixing techniques](#)). Set a third of this mixture aside for use in step 4. Wet the rest of it with an alcohol/water mixture (15:85 v/v). Add small amounts of solvent and stir for a while to allow it to soak and dissolve the dextrin before adding more. Use enough solvent to obtain a sticky wet paste.
2. Now, take a number of 30 cm lengths of hemp or cotton string. 30 cm is convenient to work with and provides long enough fuse for most purposes but longer or shorter lengths may ofcourse be used. Add one or two strings to the paste and, using your hands, knead the paste well into the string. This can be done with bare hands although it is very messy. I find it easier to do this without gloves. The mixture will not attack the skin but it is painfull, and maybe harmful, when it gets into open wounds. It is probably better to wear latex gloves.
3. When the paste is well kneaded into the string, take a length of string out and run it through your fingers to remove excess blobs of paste. Try to obtain a uniform thickness of paste. It need not be thick.
4. On a large sheet of paper, sprinkle some of the dry mixture set aside in step 1. This is most easily done using a sieve. Then, lay the string onto this layer of dry powder. Then sprinkle some dry powder over it. Some powder will stick to the wet string.
5. Take the string out of the dry powder and stretch it out on a sheet of paper. Allow it dry. The dry fuse must be handled with care to prevent the black powder coating from cracking. This would reduce the reliability of the fuse. Using a sharp knife or pair of scissors, the required lengths of fuse may be cut off.

Quick match

Quick match, like the name implies, burns very quickly. Many meters per second. It is used for connecting items together that must be ignited simultaneously, such as lancework. Another application is for igniting shells. This is not

described in the shell section elsewhere on this webpage, but shells are usually ignited with a piece of quickmatch running down the mortar to the shell and its lift charge. The mortar has no side hole. When multiple shells need to be fired simultaneously, the shell leaders are in turn ignited with a length of quickmatch. The quickmatch is then ignited by a piece of visco or an electrical ignitor. Quickmatch is easily made from black match. A length of black match running through a small diameter, thin paper tube functions as quickmatch. The sparks and hot gasses from the black match are propelled forward through the tube, igniting the black match. Thick lemonade straws may be used, but it is better to use paper tube. A tube of a single layer of paper, 5 mm in diameter is quickly made and works well. Take care not to bend the fuse too much as this will damage the black match inside, although this is less of a problem with quickmatch as it is with bare black match.

Time fuse

Time fuse is used primarily for providing a reliable, well timed delay. For example, shells are commonly timed with time fuse to explode exactly at apogee. I must admit I am not sure how many varieties exist as I have only seen one. The time fuse I have seen and used was of oriental origin and consisted of a core of a black powder-like mixture (with a high charcoal content), surrounded by a mantel of pitch, paper and string. The diameter of it all is 5 mm. The fuse is very reliable and burns at 1 cm per second. It is relatively hard to ignite, therefore it is usually primed by cutting it at an angle and applying a black powder paste or by drilling a hole through the sides and threading a piece of black match through that (this technique is called 'cross matching'). Time fuse is not easily made at home, although a thick walled paper tube with black powder pressed into it can be substituted.

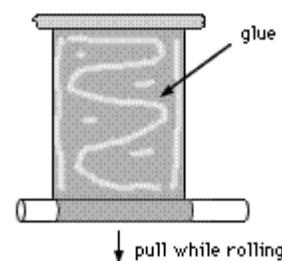
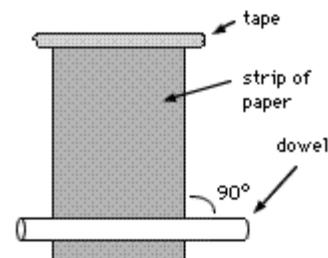
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Paper tubes

Almost any pyrotechnic device is made using paper tubes. Rockets, lances, shells, fountains, mortars, etc. etc. Tubes can be found or bought, but sometimes it is better to roll your own tubes.

Rolling your own

1. Select a strong, reasonably heavy type of paper. 70lb kraft paper works well and is sold in artists paint stores.
2. Select a glue. Wallpaper glue may be used, but I've had little success with it. If you do use it, use far less water than the package tells you to use. I personally prefer white glue. It makes strong casings and dries quickly.
3. Place a sheet of paper on a hard, flat surface. Cut it into strips as wide as long as you want the casings to be. The length of a strip will determine the wall thickness of the casings (if necessary, more strips can be used to obtain casings with thicker walls). Place one strip in front of you, and tape the far end to the working surface.
4. Place a dowel of the required diameter on the strip of paper, perpendicular to the strip, as indicated in figure 1.
5. To start, apply glue to the first edge of paper and roll it tightly around the dowel. Pay extra attention to the edges of the paper when applying glue. Press the dowel against the table and pull it towards you to prevent the paper from wrinkling.
6. Now, apply glue to the whole strip of paper. Again, make sure all the edges are well covered. Spread the glue evenly over the paper.
7. Start rolling. Pull the dowel towards you to prevent wrinkling.
8. You will most likely find that the dowel was not perfectly aligned with the paper and starts moving sideways as you roll. This can be corrected for to a certain extent by pulling more on one side of the dowel. However, it is better to avoid this as it will make the casings slightly less tight and strong. It takes some practice to master the technique well.
- 9 When the end of the paper is reached, cut the paper parallel to the tape with a sharp knife, and apply glue to the edges. Roll the last stretch of paper onto the dowel.
10. Trim the ends of the tube with a sharp knife and lay the tube aside to dry.



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Stars

Stars are the bits of burning material that are ejected by devices such as shells, roman candles and starmines. They consist of a lump of pyrotechnic composition, which is held together by a binder. There are several methods to make stars. Different methods are used depending on the composition used and the required shape or size of the star. Not all methods can be used with all compositions. Below you will find listed a couple of commonly used methods to make stars, with a link to a more extensive description.

[Cut stars](#) are quite easy to make, even in larger quantities. This method is quite usefull to try out new compositions or for producing cores for round stars (see below). It is a good method to start with if you've never made stars before.

[Pumped stars](#) are a bit more laborous to make, and require the use of special tooling. The main advantage of pumped stars over cut stars is that the stars will be more uniform in size and shape. Therefore, they will perform more consistently and are more suited to be used as cores for rolling stars.

[Pressed stars](#) are basically pumped stars, pumped with the use of a press. The main advantage of pressing stars is that the stars will be harder and require less solvent to bind (so they will dry out quicker). Especially very large stars are better pressed instead of pumped for this reason.

[Round stars](#) are probably the hardest to make. The composition is coated on cores rolling in a bowl. They slowly grow during the process, producing spherical stars. Although it takes some practice, it has some advantages none the least of which is that it allows one to make color changing stars.

[Pillbox stars](#) are simple but very laborous to make and are therefore reserved for special purposes. The stars consist of a small tube filled with composition with a piece of fuse going through it. This allows one to use compositions in stars that would normally be blown out when the star are flying through the air at great speed.

Priming

Priming a star means coating it with a layer of some easily ignitable composition that will in turn ignite the actual star composition. This is done when a type of star is not easily ignited, which is sometimes a problem in for example shells and starmines. If this is necessary depends on many factors such as the stars composition, its shape and the burst/ejection charge used. When stars are not ignited properly, they are said to be 'blown blind', and a prime is necessary. What prime to use depends mainly on the stars composition. You can find several priming formulae in the [composition database](#). When choosing a prime it is very important to watch out for 'incompatible' combinations of chemicals or compositions (see [safety](#)). A particular combination not listed on the general safety page is that of ammonium and nitrates. This is not particularly dangerous but it will actually make the ignition problem worse since this combination will lead to the formation of ammonium nitrate. Ammonium nitrate is very hygroscopic, and will make the stars slightly wet. Ammonium perchlorate stars can not be primed with black powder for this reason, and a perchlorate prime must be used.

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Lances

Lances are simple in construction, consisting simply of a paper tube filled with composition. The main difficulties in its construction lie in the filling of the tube in a proper, safe manner, the choice of composition and the means of ignition of the composition. Lances may be used attached to a wooden frame to construct texts and figures. They must then be ignited simultaneously, which can be accomplished with the use of quickmatch, a type of [fuse](#).

Essential reading

It will be assumed you are familiar with the sections on [compressing compositions](#), [mixing techniques](#) and [safety](#)

Materials

Casing: As always, paper tubes are used for casings. Tubes of 5 to 8 mm inner diameter work well. The wall thickness need not be great since it has to withstand hardly any pressure. In fact, the tube should burn away with the composition so the burning surface is able to transmit its light freely in all directions. Also, since the tube will be filled using the 'binding' method, it must allow the solvent to migrate through the walls during drying. The casing should be thick enough to protect the composition from rough handling. Roll your tubes using a glue which is insoluble in water.

Composition: A slow burning composition is usually chosen. Suitable compositions may be found in the [composition database](#), and a few suggestions are given below. If the main composition is hard to ignite, a priming may be required, especially if the lance is to be used in text and has to be ignited by quickmatch. Priming compositions are also listed in the composition database. A priming suitable for the suggested compositions will be given below.

Fuse: If the lance is to be used in text or pictures, quickmatch is commonly used to interconnect the lances. No other fuse will be necessary. Otherwise, visco is convenient to use.

Composition suggestions

	Red	Green	Blue	Priming
Ammonium perchlorate	50	54	70	
Potassium perchlorate				74
Barium nitrate		35		
Strontium nitrate	30			
Copper(II)oxide			15	
Aluminum				3
Charcoal				6
Red gum	15	16	15	12

The compositions in the table on the left may be used to produce some basic colors. These compositions are modified versions of compositions taken from several sources. They may not be the brightest or most saturated, but they are not particularly sensitive and are easy to work with. All four compositions can be mixed using the diapering method, and moistened using alcohol. Use only an extremely small amount of alcohol, just enough to make the composition into a crumbly powder. The priming composition is compatible with the compositions given, as well as with common black powder. The ammonium perchlorate compositions cannot be primed with black powder directly since formation of ammonium nitrate would result. The extreme hygroscopicity of this compound would make the lances very hard to ignite.

Construction

Bottom end plug

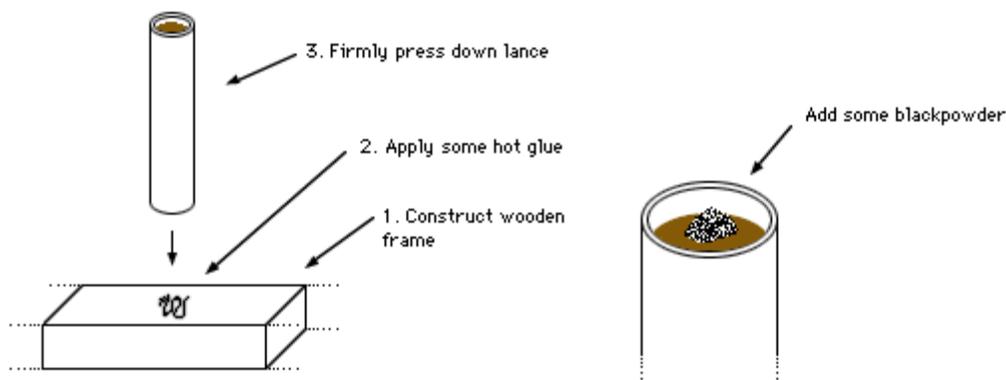
First, one end of the casing is sealed. This may be done in several ways, but a good way to do this is to ram a wad of tissue paper into the casing. Take some tissue paper, put it in the tube, slide a dowel in, press the tube against a flat, strong surface and give the dowel a few strong blows with a hammer. The paper should form a strong plug. Use enough tissue paper to give a plug about half as thick as the inner diameter of the casing.

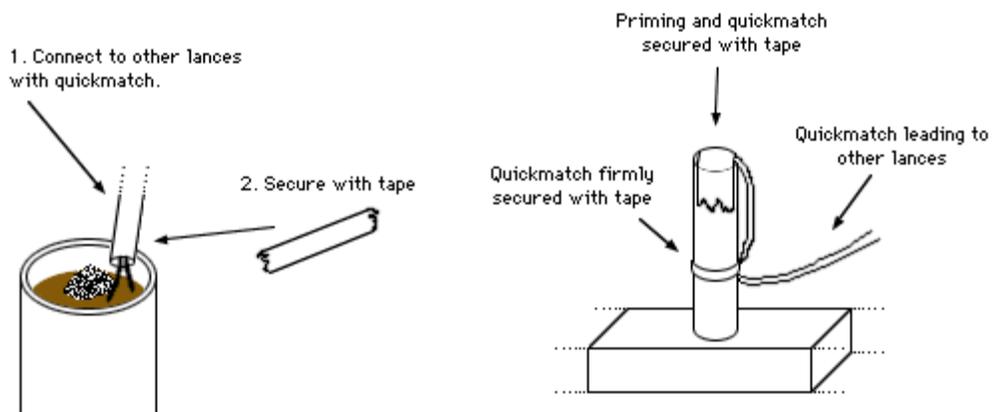
Filling

- 1) Prepare the composition of choice and slightly moisten it with an appropriate solvent. Like mentioned, add just enough solvent to obtain a crumbly powder.
- 2) Then, scoop a small amount of moistened powder into the casing. Use no more than will give a layer as thick as the inner diameter of the casing.
- 3) Using a dowel, slightly compact the powder. Press the dowel down using just your hands. Don't apply much pressure, just enough to press the crumbly powder into a solid coherent mass. The dowel used should be 1 to 2 mm smaller than the inner diameter of the casing.
- 4) Repeat steps 2 and 3 until the casing is almost full. Leave about 1 cm unfilled.
- 5) Now, prepare the priming composition and moisten it. As before, use just enough solvent to make the composition into a crumbly powder. Using steps 2 and 3, apply a layer of about 5 mm thickness.
- 6) If the lance is to be used in the construction of text and pictures this step can be skipped. Take a 2 cm length visco and insert it in the casing, allowing it to rest on the layer of priming composition. Add some more priming composition, and compress it as before (step 3). Add enough priming to fill the remainder of the casing. This should hold the visco in place.
- 7) Set the casing aside to dry. Allow it dry thoroughly (which takes a few days, or weeks even depending on the conditions). Do not apply heat in an attempt to speed up the drying process.

Constructing 'lancework'

One of the most interesting applications of lances and probably one of the best known as well is in lancework. Lances are attached to a frame, forming a text or picture, and simultaneously ignited using quickmatch. The frame is usually constructed from wood. There are several methods to attach and interconnect the lances. My method is to glue the bottom of a lance to the frame using hot melt glue. Some black powder is then dumped into the 5 mm of casing left unfilled (step 6 was skipped), and a piece of quickmatch is secured with tape. The following pictures illustrate the principle.





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Fountains

Under construction, sorry

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Rockets

This page describes how to build various small rocket motors. These can be used to carry small effect charges up into the sky. Simply attaching them to a stick will provide adequate stabilisation during flight. The basic desing of rockets has hardly changed since they were invented by the Chinese, centuries ago. In fact, the black powder rockets described on these pages employ the same basic design, materials and compositions used by the Chinese.

Making reliable rocket motors is a bit of a challenge, and it usually takes a while to achieve reliability. So be patient, don't despair when even your tenth attemp blows up on the launch pad. Even a detailed description of a design that works for someone else is not garantueed to produce a functional rocket in your shop. Differences in propellant, ramming force etc. can lead to significant differences in performance.



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Tools

Although not really required for black powder rockets, some special [rocket tools](#) will make the job easier and safer. Such tools are essential for making the two other types of rockets described below.

Rocket motors

[Black powder rockets](#) are the most basic type of rockets. They are the least likely to fail, and the low sensitivity of black powder makes it easy to work with, making these ideal rockets to start with if you are new to pyrotechnics.

[Whistling rockets](#) An interesting pyrotechnic phenomenon is ability of certain composition to produce a characteristic whistling sound if properly pressed into tubes. These compositions can also produce sufficient thrust to allow their use as a propellant. Whistling rockets are more difficult to make than black powder rockets, mainly because the propellants used in whistling rockets are far more sensitive than black powder. Also, the rocket dimensions are a bit more critical, narrowing the margin for success.

[Strobing rockets](#) Some compositions tend to 'strobe', i.e. burn in an on-and-off manner. This can be exploited to produce a range of interesting effects, one of which is the strobing rocket. Difficulty level of making these is probably comparable to that of whistling rockets.

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Tourbillions

Tourbillions are one of my favourite pieces. Simple and quick to construct, and fun. They consist of propellant-loaded tubes with a side directed nozzle and an attached helicopter wing. Spinning quickly, they climb several meters into the air until they run out of propellant and ignite the effect charge. Their lifting capacity is marginal, so the effect charge in my tourbillions usually consists of a bit of flash powder for a healthy bang, perhaps with bit of titanium for sparks. This page will show you how to build a 12 mm tourbillion with a flash heading. If desired, larger or smaller tourbillions can be made using the same method.

Essential reading

It will be assumed you are familiar with the sections on [compressing compositions](#), [mixing techniques](#) and [safety](#).

Materials

Casing: For a 12 mm tourbillion we need a casing of 12 mm inner diameter, 3 mm wall thickness and 90 mm length. This is a bit longer than used for a rocket of the same caliber. The extra length will be used to accomodate the effect charge.

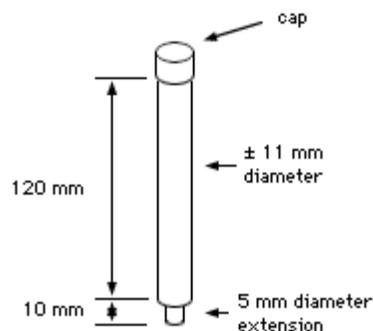
Propellant: Most rocket propellants are suitable, particularly those that produce interesting sparks or colors. The following composition works well, and several more may be found in the [composition database](#)

Potassium nitrate	68
Charcoal	14
Sulfur	9
Aluminum	9

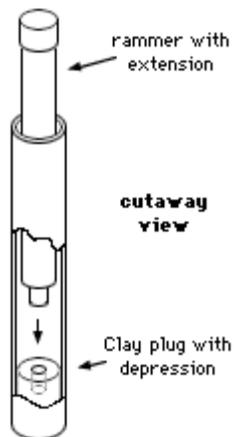
Effect charge: A little bit of flash powder will be used for the report. Please do keep in mind that flash powders are among the most sensitive -and- powerfull mixtures used in fireworks. They should be treated with extra care. Pay extra attention to your methods to avoid static electricity and friction as much as possible. Also, do not prepare any more than a few grams at a time. A little goes a long way. Our tourbillion will only required 0.3 grams for a respectable BANG. There are many flash powder compositions that work. The most commonly used flash powder is probably flash #2 from the [composition database](#), a mixture of 70 parts potassium perchlorate and 30 parts aluminum powder. To obtain the best results, use a very fine and reactive grade of aluminum, preferably german black. If you like, you can add a little bit (say +5%) of titanium to add some interesting sparks to the effect.

The wing: Coffee stirrer bars are perfect for forming the wing. They are cheap and easy to find at least where I live. If you have a hard time finding these, any other piece of thin, light wood will do. Use a piece of approximately 11 cm length, 1 cm width and 1 mm thickness.

Clay: The nozzle and end plug are formed from clay, much like as is done in the construction of rockets. As will be described shortly, the nozzle shape is different though. Bentonite, kaolin and ground kitty litter all work well.



Tools: A sleeve and rammer, such as used in the construction of rockets (see [rocket tools](#) section) are used for this project as well. Besides a flat-ended rammer an unconventional rammer will also be needed (see figure). With some patience it can be made by evenly filing down one end of a straight rod. Alternatively, you could drill a lengthwise hole of 5 mm diameter in the center of a flat ended dowel and fix a short length of 5 mm rod in that (much like as is done in the construction of a spindle, also described in the rocket tools section).



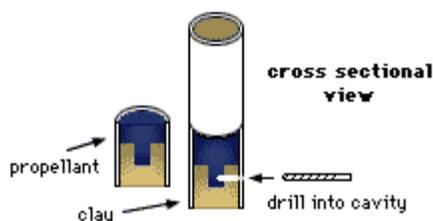
Construction

Nozzle end

Buzzbombs differ from rockets in that the exhaust from the nozzle is projected sideways, exerting a torque. Clay is used to provide a more or less erosion resistant exhaust hole. The clay is pressed in two stages. First, a 12 mm plug of clay is rammed or pressed into the casing using the flat rammer. A sleeve may be used for more consistent results. Then, using the rammer from figure 1, a second layer of clay, approximately 10 mm thick is formed. This layer should have a cylindrical cavity of 10 mm depth and 5 mm diameter. The cutaway view in figure 2 illustrates the principle.

Propellant, end plug and exhaust hole

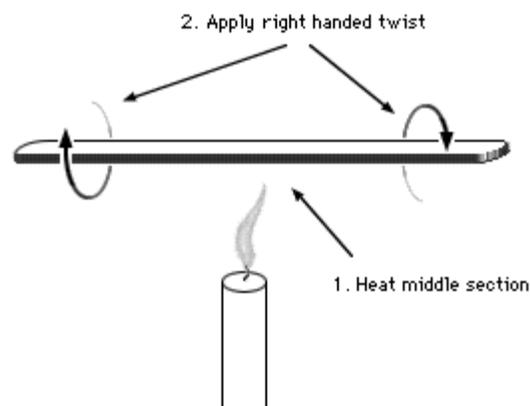
Ram or press the propellant in small increments, each no more than will give a layer as thick as half the casings inner diameter (i.e. 6 mm) to prevent wrinkling. The first two increments are compacted using the extended rammer, the rest with a normal flat rammer. The last 12 mm of the casing are filled with clay to form the end plug.



The exhaust hole is drilled through the side of the casing. This is a somewhat dangerous operation since it causes quite a lot of friction but as we do not need to drill a great length through the propellant and the propellant is quite unsensitive, I consider the risk to be acceptable. (ofcourse, a blast screen and proper protective clothing should still be used). With the drill set at low speed, drill a 3 mm hole through the side of the casing, 17 mm from the end. Drill halfway through the casing (i.e. 9 mm deep, assumin the casing is of 18 mm outer diameter), the hole should reach just into the (now propellant filled) cavity in the clay plug, as illustrated.

Forming the wing

As said, the wing is formed from wood. Wood can be bent by means of a method used to build ship hulls a few centuries ago. The wood is heated, slowly bent into shape and kept that way for some time. It is then allowed to cool. When it is then removed from the clamps it retains its shape. Hold the wood by the ends between thumb and finger and apply heat to the middle by means of a hot air gun or candle flame. Heat it well, but take care not to cause charring. Then, twist by an angle of approximately 45 degrees. Hold the wood in this shape for a short while, still applying heat . Then, keeping it twisted, allow it to cool down.



The direction of the twist is important. Though both left-handed and right-handed propellers will work it is best to decide on one direction in order to prevent yourself



right handed

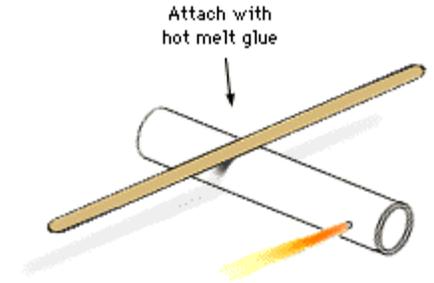


left handed

from getting confused. It will be assumed that a right-handed propeller is used from here on to prevent things from getting unnecessarily complicated. To determine the twist of a propeller look lengthwise along the propeller, keeping the end nearest to you horizontal. The schematic drawing on the left shows what both propellers should look like.

Assembly

Glue the wing to the casing with some hot melt glue. Take care to orientate the exhaust hole properly with respect to the wing. The situation shown is as it should be for a right-handed wing. For a left-handed wing, rotate the casing 180 degrees around it's lengthwise axis. Insert a piece of fuse into the exhaust hole (5 cm of visco is adequate) and fix it in place with a drop of hot melt glue or red gum bound blackpowder (5% red gum, 95% black powder).



Use and dangers

Place on the ground, as illustrated above with the casing resting on the ground and the wing on top. Light fuse and retreat. Keep well away from these items, at least 10 meters. If the wing is accidentally attached in the wrong orientation, the tourbillion will bounce around on the ground instead of climbing into the air. Like rockets, they may explode if the propellant is not compressed well. The end plug or nozzle may also be blown out which can be extra hazardous since it will be projected horizontally instead of up- or downward as in the case of a rocket.



[A movie](#) (752 kb) of a tourbillion made as described.

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Starmines

Starmines are devices that fire a cloud of stars up into the sky. The effect is short, but spectacular and they are very commonly used in professional displays. I've heard of several different ways to make starmines, and the method described here is just the way I do it. Other methods may be better (this page needs updating), but it works well, especially for smaller to intermediate sizes (say up to 5 cm diameter). The starmine described here consists of a thickwalled paper tube that is tightly sealed by a wooden or clay endplug on one side. The other side is only sealed by a paper plug. In the mine, a lift charge and some stars are placed. The entire device is glued to a wooden base. When the mine is fired, the paper plug will give way, the stars are shot upwards and will reach 10...20 meters height. Then they rain down, and burn out before they reach the ground. The effect is spectacular, especially with the somewhat larger ones. For a first starmine, 3 to 4 cm inner diameter is a nice size to start with. Smaller is much less spectacular, and larger is more dangerous. Also: in general it is better to start out small.

Essential reading

It will be assumed you are familiar with the sections mentioned in all former projects as well as with [black powder](#), [fuse](#), [stars](#), and [safety](#)

materials

Casing: A 17 to 20 cm long paper [tube](#) with an inside diameter of 3 to 4 cm, and wall thickness of 5 mm or more.

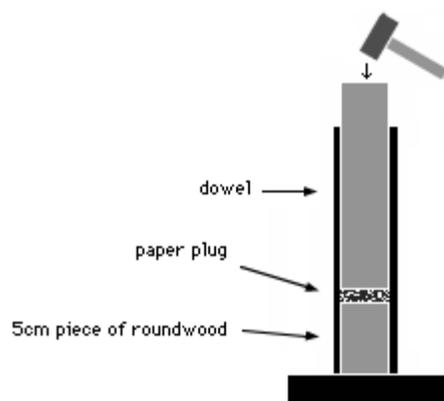
End plugs Toiletpaper or tissuepaper is used for one end plug. The other is either made from wood, in which case you need a wooden endplug of 1 to 1.5 cm length that fits the dowel, or clay. If clay is used, Bentonite clay works well. I use ground up kitty litter myself (see [chemicals](#)).

Fuse: Visco [fuse](#) works fine. A long delay between ignition and effect is preferred. I personally prefer to have a 20 second delay. Quite long, but it allows you to not only reach a safe distance but starmines also look much better from a distance.

Lift charge: [Black powder](#) works well.

Stars: Some stars are needed ofcourse. Use between 30 and 50 [stars](#) of 1 to 1.5 cm diameter.

The 'open' end



You want the starmine to remain intact (withstand the pressure from the lift charge) long enough to build up sufficient pressure to fire the stars high up in sky. On the other hand, you want to be sure that the stars are actually fired. Not crushed or burst through the sides of the mine. Therefore, the 'open' end should not be actually open, but resist the lift charge for a while, while it should be the weakest part of the device so that you are sure it will burst there. Think of it as a shell with an intended unsymmetrical break.

Take the 5 cm piece of roundwood. Place this piece of wood upright on a hard surface, and slide the tube over it. Then stuff several wads of toiletpaper in the one end of the tube. Place a dowel in the tube and use a hammer to compact the paper tightly in the tube. Then take the dowel and the piece of roundwood out.

The paper will form a surprisingly strong plug in the tube, although less strong than the walls of the tube. Its thickness should be about 1 cm. After a few attempts you will know how much paper to use to form a plug of this thickness. To get consistent results, use the same amount of paper every time. If you ever

decide to make a larger diameter mine or the stars do not reach an appropriate altitude, use more tissuepaper or ram it more tightly (try the latter first).

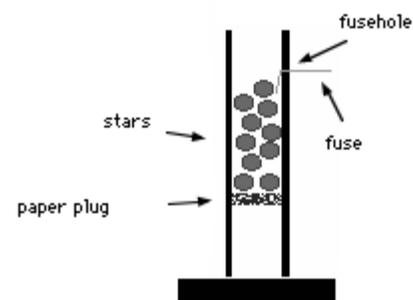
The fuse

It is better to add the fuse before the lift charge and stars. The fuse is inserted through a hole in the side. So first drill a hole with a small diameter drill, just 2 cm of the bottom end of the mine (so that it will be slightly above the end plug). I use a 1 mm drill and insert a 20 cm piece of visco fuse. More for bigger mines. I bend the fuse inside the mine and secure it with a drop of hot melt glue or a piece of paper tape. twist it around the tube gently, and tape it lightly so that it won't be in your way (you could damage it) during the next steps. Like mentioned, I use 20 cm of visco. That allows about 17 seconds to get away. You need that much time not only to be at a safe distance in case something should go wrong but also because a starmine looks so much better when viewed from a distance.

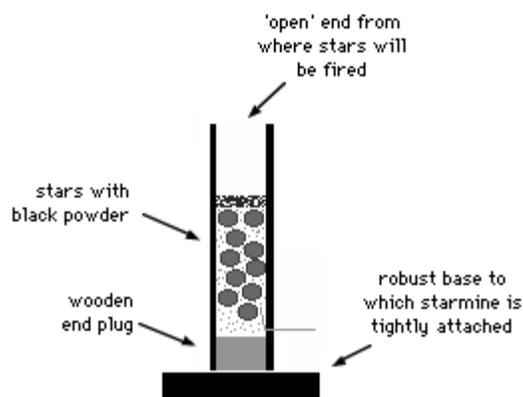
The contents

The starmine contains some stars and a lifting charge. You can use just about any type of stars, including cut stars and rounds stars. Use stars of 1 to 1.5 cm size, and fill about 3/4 of the starmine with them. Add the stars in small portions taping the case after each addition to settle the stars.

Black powder is used for the lift charge. Even black powder of inferior quality (black powder made without a ball mill, also known as pulverone) can be used. If you use good quality black powder a few grams (2 to 3 grams) will do. Otherwise, fill the starmine with black powder completely. That is, leave 2 cm of space for the end plug but cover the stars with black powder. Tap the case to settle the powder.



The endplug and base



Finally, glue the endplug in the tube. I use hot melt glue, which seems to cause no troubles. Other glues may work fine too. Make sure the endplug fits the tube tightly. If required, tape a few layers of tape (without wrinkling) around the plug to increase its diameter somewhat. Then glue the entire starmine on a robust wooden base. Always do that, since it will prevent the starmine from falling over when it is placed on an uneven surface. It is a good idea to bury the starmine partially, leaving the fusehole just above the surface.

Firing your starmine

Pick an open piece of terrain for firing the mine. An open field without cattle is perfect. You cannot damage things, and the effect can be fully appreciated in the open. The main dangers of the starmine are the fire hazard of the burning stars and the mine falling over, launching the stars horizontally (which can be avoided by using a proper base). Take enough distance, otherwise you risk getting burning stars or glowing ashes all over you.

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Cylindrical shells

Cylindrical shells are said to have been invented in Italy, centuries ago. Hence, they are also known as 'Italian shells'. They are easier to make than round shells. The pattern of stars (or 'break') produced by a cylindrical shell tends to be somewhat less symmetrical than that of a round shell. Because of their simple construction and because there are no stars involved, salutes are often constructed as cylindrical shells. An interesting variety of the cylindrical shell is the multibreak shell, which consists of a number of cylindrical shells, stacked on top of each other and interconnected with timefuse. These produce a number of breaks at regularly timed intervals.

This page describes the construction of a small (3.5 cm) cylindrical shell. Though small these shells can still produce a nice break some 20 meters across using black powder as a burst charge. The procedure can be scaled up to make shells of larger caliber.

Essential reading

It will be assumed you are familiar with the following sections: [black powder](#), [stars](#), [rolling casings](#), [fuse](#) and [safety](#).

The materials

Burst charge. [Black powder](#) works well if your casings are sufficiently strong. Though more energetic burst charges (flash powder, whistle mix) are often recommended for small shells, I find it is possible to obtain very satisfactory results using just black powder, and it is much safer to work with. Also, flash powder can disturb color perception if the flash is too bright. Ofcourse, if you use stars that are based on a chlorate composition (which is strongly discouraged for beginners) black powder burst should never be used as it contains sulfur.

Stars. Round or cylindrical (pumped/pressed) [stars](#) are best. Cut stars can be used just as well, but round or cylindrical stars will allow you to arrange the stars more evenly giving a more symmetrical break. The stars can't be large: Somewhere between 5...10 mm, depending on burn rate.

Timefuse. Visco (as will be described) works well for these small shells. For larger shells, proper [timefuse](#) is better.

Glue. White glue or your own favourite glue for constructing the casing and hot melt to seal the fuse. You can use white glue instead of hot melt, but hot melt is easier/quicker to work with.

String. Hemp string is traditional. You can probably use any kind of strong, thin string. Nylon for instance works well too.

Casing. For a casing you will need a cardboard tube, and two cardboard end discs. You can ofcourse use premade tubes, but it is easy enough to roll your own [tubes](#) and the advantage will be that you can make them any size you like and fits your mortar tube(s). Use a dowel with a diameter of about 15 mm less than the inner diameter of your mortar tube. The extra space is for casing thickness, string and some extra to make sure the shell doesn't fit too tightly in the mortar. The tube should be 2 to 3 times long as it is wide. For a 2.5 cm diameter dowel, Keep rolling untill you have a wall thickness of about 2 mm.

Construction

The two end discs should be made from non corrugated cardboard and should not be too thin. Pretty thin cardboard can be used for shells as small as those described here, but larger shells require correspondingly thicker cardboard. Lacking any real thick

cardboard, I use the thinner variety and glue two discs together to obtain a single disc of twice the thickness. The discs should be the same diameter as the dowel used to roll the casing with. Slide the casing onto the dowel, and place one end disc on top, as shown, leaving about 5 mm extending over the end disc.

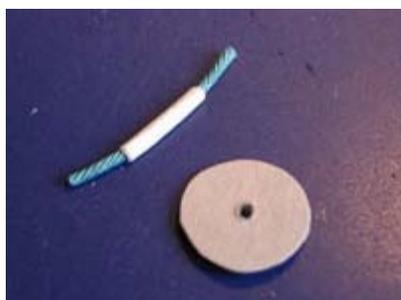


Put some glue on the end disc...

...and fold over the sides of the casing. Press the casing firmly on a hard flat surface for a few seconds until the glue holds well. If the end disc fits perfectly in the casing inner diameter, the glue and folds will prevent any sparks or hot gas from the lift charge from entering the casing and igniting the shell prematurely (ie inside the mortar, which is known as a 'flowerpot').

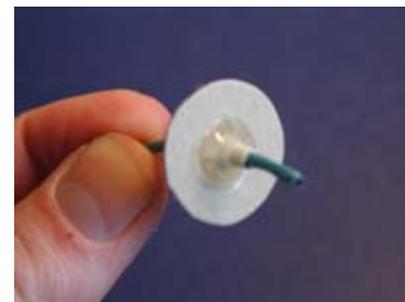


To get a symmetrical break, it is a good idea to arrange the stars along the sides of the casing and use a 'core' of burst powder. Use a small paper tube to keep the core clear of stars, as shown, and arrange the stars around the sides. In the pictures, cut stars are used but using round or cylindrical stars is better. This will allow you to arrange the stars around the sides more symmetrically. When full, sprinkle some black powder between the stars to fill up the voids between them.



Visco can be used as a timefuse. It is cheap, small and reliable. It is also convenient in that it doesn't need priming. The visco needs to be partially wrapped in paper for this purpose. Simply use a 7cm long strip of masking tape, 1 cm wide, and wrap it tightly around the visco. If you make the paper strip wider, the delay will be longer. Make sure at least 0.5 to 1 cm of bare fuse extends from the paper on both sides.

Now take the second end disc and drill, cut or pierce a hole in the center. Stick the fuse through this hole, and seal it well with hot melt glue. Allow the hot melt to cool before proceeding with the next step.



Place the end disc with the fuse, hot melt side up, in the casing. Tap the casing and press the end disc firmly on the contents. This will make the shell a little more rigid and resist the 'kick' from the launch better.

Put glue on the end disc and fold over the casing. Press firmly to make sure the glue holds well.



All that remains is strengthening the casing with string, called 'spiking'. With larger shells the string is often tied to the fuse to start, but this is not a good idea with these small shells since it may fold the fuse, reducing its reliability. You can instead hold the string in place with your fingers during the first wrap, and wrap it over itself to hold it into place. Make sure the string goes at least 8 times over the length of the casing and then 4 - 6 times around the sides as tightly as possible. Wrap the string over itself again to finish, and secure the knot with a drop of hot melt glue.

Once the stringing is done, write on the shell what's inside so that you won't forget if you make several.

Launching the shell

You will need a mortar that is a few mm wider than the shell. There must be 3 to 4 mm extra space between the mortar wall and the shell on both sides. Also, to reduce the amount of work of making a shell I omitted the lift bag/cup that is often used with larger shells. Instead, I use 4 cm diameter HDPE mortars with a fuse hole in the side and simply dump 3 to 4 grams of black powder in the mouth of the mortar, followed by the shell. This works fine. Ofcourse, reloading the mortar must be done cautiously as glowing embers may ignite the black powder lift charge when you dump it in the mortar. Don't have any loose shells nearby, or keep them well covered from any sparks. Don't hold any body parts over the mortar when you (re)load it.

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Compressing compositions

Quite often a powder needs to be formed into a solid mass to control the burn rate, for example in the construction of fountains, rockets and lances. Depending on the composition used and the application, different methods may be used to accomplish this. Ramming and pressing are the most commonly used methods. Due to the shocks, friction and enormous forces involved in these processes, they can be dangerous. Mixtures may ignite when rammed or pressed and it is therefore of the utmost importance that the techniques for doing this as safe as possible are learned. Another commonly used method is to hold a composition together with a binder. The binder of choice depends on the particular composition. This too can be dangerous if an improper binder or solvent is used. Below, each method is described.

[Ramming](#)

[Pressing](#)

[Binding](#)

Ramming

This method is used to fill tubes with composition. Small amounts of powdered composition are added to the tube, a dowel is inserted and the powder is compacted with a hammer. Obviously, this method can only be used for very insensitive compositions. Mixtures consisting of nitrates, charcoal and sulfur are commonly rammed. Many rocket propellants and fountain compositions are made with just these three chemicals. However, metal powders are often added to these mixtures for spark effects and this makes them more sensitive. Although these mixtures are also commonly rammed, it is good to know about their increased sensitivity. Mixtures containing chlorates or perchlorates should never be rammed. They are much more sensitive than nitrate based mixtures. Such mixtures are pressed or bound instead.

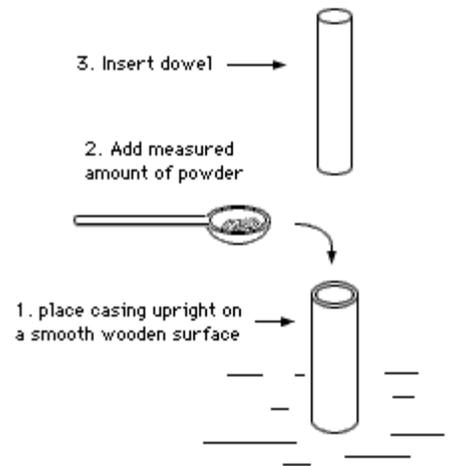
From comparing accounts of accidental ignitions during ramming, it seems that the most likely thing to happen is that the dowel will be blown out of the casing, sometimes with force, and the composition will then steadily burn away. If you are wearing proper protective clothing (eye and ear protection, face shield, heavy gloves and heavy (eg leather) apron are minimal), followed the safety tips in the [safety](#) section and did not lean over the casing while ramming, the risk of serious injury is minimal.

Perchlorate and chlorate based mixtures are not only more sensitive, they also burn at a greater rate. In case of accidental ignition these mixtures are more likely to cause an explosion instead of a relatively harmless steady combustion. Protective clothing will provide little protection against explosions, and this is another reason why perchlorate and chlorate based mixtures should never be rammed.

1) Place the casing to be filled on a smooth wooden surface. Sometimes, when the casing is relatively thin, a 'sleeve' is used to prevent it from splitting. For more information on this, check out the [rocket tools](#) and [rocket construction](#) pages.

2) Add a small amount of loose composition to the casing. Use no more composition than will give a layer as thick as the casings inner diameter after ramming, or the casing may wrinkle. Also, the powder may not be fully compacted. This often results in inconsistent performance and explosions.

3) Tap the casing to settle the powder, and insert the dowel. The dowel should slide easily into and out of the casing, yet there should be little clearance between dowel and casing. As a rule of thumb, use a dowel 1 mm smaller than the inner diameter of the casing if the casings inner diameter is less than 20

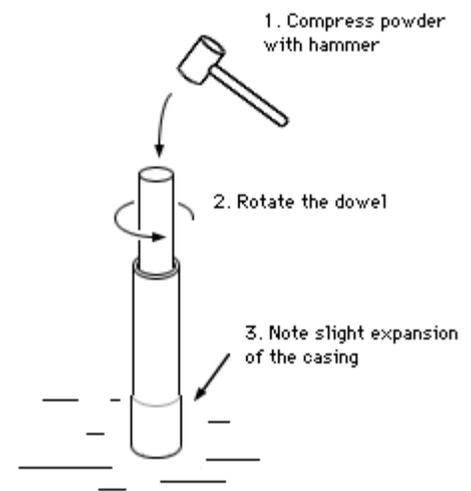


mm. If larger casings are used, use a dowel 2 or 3 mm smaller than the casing.

4) Push the dowel down firmly using your hands. This will compact the powder a bit and allow most of the air trapped between the grains to escape.

5) Now, using a wooden or rubber-coated hammer, give the dowel a few blows. Everyone seems to have his or her own method, but in any case it is important to be consistent: use the same number of blows everytime, and try to use about the same amount of force. My method is to give three intermediately strong blows, lift the dowel slightly, rotate it a third of the way, give another three blows, lift, rotate and ram once more and then repeat, this time using stronger blows.

6) When the casing is filled to the required level, remove the sleeve if used and inspect the casing. It should not be wrinkled, and a slight expansion of the casing is usually a good sign. A very tight sleeve may prevent the casing from expanding however, even if enough force was applied.



Pressing

Pressing produces less shocks and friction than ramming, reducing the risk of accidental ignition. It also allows the operator to be at a distance from the composition, and a blast screen can be mounted in between. Therefore, pressing is a much safer method of compression than ramming. More sensitive compositions can be used, increasing the range of effects achievable. Compositions that are unsensitive enough to be rammed may be pressed instead, possibly increasing safety. So, even though you can do without, after some time you will probably want to construct a [press](#). A simple solution for small items is to use a large vice for pressing, as is described on the press page.

1) If necessary, insert the casing in a sleeve.

2) Add a small, measured amount of composition. Like before, use no more than will give a layer as thick as the inner diameter of the casing to prevent wrinkling and incomplete compression.

3) Insert the dowel. As explained in the ramming section, it should slide easily in and out of the casing but fit the casing well. Insert the casing in the press.

4) Now, position yourself behind the blast screen. Hopefully needless to say, a blast screen is no excuse for not wearing protective clothing. In case of accidental ignition an explosion is very likely since the press provides extra confinement. While the dowel was free to move out of the casing in ramming and allow a way of escape for the gasses generated, during pressing it is not. So, as always, wear at least heavy gloves, face shield and a leather apron.

5) Now, compress the powder. Try to exert about the same amount of force everytime, to improve consistency. Some people use a pressure gauge to actually measure the force. Others simply try to judge the force they are exerting themselves on the press. If the performance of your items is inconsistent, reconsider your technique of pressing first. In general it seems best to apply as much force as possible without splitting the casing.

6) Wait for a few seconds, then release the pressure.

7) Remove the casing from the press, and repeat steps 2 through 6 until the casing is filled to the required level.

8) Inspect the casing. It should not have wrinkled, and slight expansion is usually a good sign. A very tight sleeve may prevent the casing from expanding however, even if enough force was applied.

Binding

This method relies on a different principle than the other two. A binder is added to the powdered composition, some solvent is added, the dough is shaped as required and allowed to dry. This method has many applications, probably more than it is commonly used in. In the past few decades, polymerising binding agents have found increasing application as well. These do not need to be dissolved in a solvent and can therefore be used to manufacture large solid masses of composition in non-porous casings. These binders find widespread use in rocket propellant manufacturing, but I've heard of people using the same technique to produce stars and lances.

This method produces very little friction and may be used with comparatively sensitive compositions. However, the use of solvent can cause some other difficulties. The binder/solvent system used must be compatible with the composition. For some more details, read the 'incompatibilities' section on the [safety](#) page.

1) Prepare the composition. Following the instructions, add the binder as a dry powder to the composition or dissolve it in a solvent. If a curing (polymerising) binder is used, add the monomere.

2) If the binder was added as a powder to the composition, spray the composition with a solvent. If the binder was dissolved, wet the composition with the required amount of solvent. In general, the first method is better since this allows control over the amount of binder used. Indications for the use of solvent are generally quite vague (along the lines of 'make the composition into a wet paste', or 'a stiff dough'). This page is not different in that respect, and this is where some experience comes in. As a rule of thumb however, it is best to add as little solvent as possible. Add small amounts of solvent, mix them well into the composition, and stop when the right consistency has been achieved. If a polymerising binder is used, the exact amount should be stated since it usually constitutes a significant part of the composition. To start the polymerising process, different methods are employed depending on the polymere. We will assume that the process is started by adding a initialiser or hardener, which may be mixed in at this point. Mix it in well with the rest of the composition, so the polymerisation takes place homogenously throughout the mass. Note that the polymerisation reaction may release heat which could cause spontaneous ignition of some mixtures. Especially if too much hardener is added the polymerisation reaction takes place at a great rate. So, take precautions accordingly.

3) Following the instructions, shape the composition as required. If it is inserted into a casing, a thin casing is usually used to allow the solvent to migrate through the walls and evaporate.

4) Allow to dry thoroughly. Depending on the solvent, temperature, ventilation, the amount of composition used, the surface area of the shaped mass and the casing surrounding it, drying time may vary from minutes to months! Do not try to speed up drying using heat; just be patient.

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A collection of pyrotechnic compositions

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Number of Compositions: 299

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Introduction, disclaimer, credits and notes on this document

Introduction

This book is a compilation of all the compositions I could gather from the net. I have copied them from various sources retaining as much of the original comments and tips, but have not tested them. Hence, I cannot provide much information on the performance, sensitivity, etc of the actual mixture. While the list contains several excellent compositions from reputed sources, it also contains several dangerous, outdated compositions. Please experiment cautiously and on a very small scale when testing any of the compositions in this database and test them thoroughly before using them in actual projects. If you find anything that you feel should be added, changed, deleted or properly credited, please let me know. I can be reached at wfvisser@dds.nl.

Disclaimer

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Credits

Many people on the net have provided, knowingly or not, much of the information that went into making this document. Whenever possible, I tried to include the name and address of the poster of the composition and a short

reference to the literature it originated from. It was not always possible for me to trace a composition back to its original source, and if you feel anything should be more properly credited or removed or if your adress or name is spelled incorrectly or is outdated, please let me know.

Important note

Note that I have tried to give a short comment on the most obvious safety aspects of these mixtures, but have been inconsistent in doing so. I also left out most of the details and the standard precautions that should be taken during preperation and handling of the mixture or its components. Procedures for safe mixing and other operations are considered known, and so is knowledge of combinations of chemicals that should never be used. The list does contain several dangerously sensitive mixtures. It is a must to obtain additional information from reliable sources on the safety of any of these compositions before experimenting with any of them.

General notes

All parts are by weight. The abbreviation 'qs', which is sometimes used, stands for 'quantity sufficient'. In these cases the required amount is not very critical, and with some experience it is not hard to guess how much should be used. Additional percentages are given as '+x%', where the x% is a percentage of the total weight of the other chemicals. Sometimes compostions must be stabilised: Magnesium or magnalium must always be treated with potassium dichromate. Iron must always be coated with tung- or linseed oil. To all compositions containing both nitrates and aluminum an additional +1% boric acid must be added. Compositions containing both sulfur and chlorates or copperammonium complex salts in combination with nitrates or chlorates are extremely sensitive and should never be used. Compositions containing aluminium or magnesium incombination with nitrates and chlorates should also never be used.

Last updated: august, 1998

Chapter 1: Rocket propellants

Rocket propellant #1 ('Candy Propellant')

Source: rec.pyrotechnics

Comments: This propellant is often refferred to as "candy propellant".

Preparation: It is best prepared by melting the potassium nitrate and sugar together, but this is a dangerous operation and could result in accidental ignition during preperation. Dry mixing is possible and much safer but produces lower quality propellant.

Potassium nitrate.....74.5
Sugar.....25.5

Rocket propellant #2

Source: rec.pyrotechnics

Comments: The propellant has a burn rate of 0.0385 inch/sec at 100psi and a burn rate of 0.04 inch/sec at 300psi. Burn temperature is approx. 1800K. and ISP=180.

Preparation:

Ammonium nitrate.....85-90%
Elastomeric binder (HTPB or other urethane plastic).....?

Rocket propellant #3

Source: rec.pyrotechnics

Comments: Stinks like ammonia when mixed, and hardens faster than normal epoxy curing time. Suggestions for rocket dimensions: 1" rocket tube, 3" fuel length, Durhanm's water putty nozzle 3/8" thick, and 5/16" diameter. Core in

center of fuel about 3/8" diameter through the length.

Preparation:

Ammonium perchlorate, 200 micron.....80
Resin (Epon 815 epoxy & curing agent U).....20
Copper chromite.....+1%

Rocket propellant #4

Source: Composition from the text 'The Incredible Five Cent Sugar Rocket' distributed on the internet by the Teleflite corporation.

Comments: Mixture is somewhat hygroscopic. Low impulse propellant.

Preparation:

Potassium nitrate.....63
Sugar.....27
Sulfur.....10

Rocket propellant #5 (Whistling)

Source: rec.pyrotechnics archive. Article by A.J. Smith

Comments: Loud whistling rockets can be made with this. The author of the text this composition was taken from used it in nozzle-less whistling rockets. The rocket casings were 3/4 inch inner diameter, and 3.25 inch length. The fuel grain ended 1/8" from the rear end of the motor tube.

Preparation: 1. Mix the iron oxide with the potassium benzoate and mill this mixture until a very fine powder is obtained. 2. Melt the petroleum jelly in a beaker on low heat. Turn the hot plate or stove off. Make sure no sources of heat or sparks are present before proceeding with the next steps. 3. While stirring, add 5 parts of toluene to each part of petroleum jelly by weight. Laquer thinner can be substituted for toluene when pure toluene is not available. Continue stirring until the petroleum jelly has completely dissolved in the solvent used. 4. Add the petroleum jelly to the potassium benzoate/iron oxide mix and stir the mixture until it becomes homogenous. 5. Then, slowly add the potassium perchlorate while stirring continuously with a wooden spoon for several minutes until homogenous. At this point, the mixture usually has a consistency of thick soup and the beaker is warm to the touch. If the mixture seems too dry or thick, extra toluene or laquer thinner can be added at this stage. 6. Spread the composition out in a layer about 1/2" thick on kraft paper over newspapers to dry overnight. It is important that the mixture has thoroughly dried before pressing motors. A slightly damp mix can cause some shrinkage of the propellant grain over a period of days or weeks, causing the rocket to explode when ignited. 7. When the composition has dried overnight, carefully run the mixture through a 20 mesh sieve twice and store in a paper container so that trace amounts of solvent can evaporate. After several days, the mix is ready to press.

Potassium perchlorate (fine mesh).....64
Potassium benzoate.....32
Red Iron Oxide, Fe₂O₃.....1
Petroleum jelly.....3

Rocket propellant #6 (KNO₃ propellant)

Source: rec.pyrotechnics. Posted by Chris Beauregard <cpbeaure@descartes.waterloo.edu

Comments: The burning rate of these rocket fuels depends much less on pressure than that of black powder. This widens the acceptable limits of the ratio nozzle area/fuel surface area.

Preparation:

Potassium nitrate.....72
Carbon.....24
Sulfur.....4

Rocket propellant #7 (NaNO₃ propellant)

Source: rec.pyrotechnics. Posted by Chris Beauregard <cpbeaure@descartes.waterloo.edu

Comments: The burning rate of this rocket fuels depends much less on pressure than that of black powder. This widens

the acceptable limits of the ratio nozzle area/fuel surface area.

Preparation:

Sodium nitrate.....69
Carbon.....27
Sulfur.....4

Rocket propellant #7 (Zinc/Sulfur)

Source: rec.pyrotechnics

Comments: Burns very fast, producing lots of smoke. It is not a very effective propellant due to its low energy density.

Preparation:

Zinc.....67.1%
Sulfur.....32.9%

Space Shuttle Boosters propellant

Source: NASA homepage

Comments:

Preparation:

Aluminum powder.....16
Ammonium perchlorate.....69.9
Fe₂O₃ catalyst.....0.07
Rubber based binder of polybutadiene acrylic acidacrylonitrile.....12.04
Epoxy curing agent.....1.96

ESTES C-class rocket engine propellant

Source: rec.pyrotechnics, Composition from 1994 US Dept. of Labour Material Safety Data Sheet.

Comments:

Preparation:

Potassium nitrate.....71.79
Sulfur.....13.45
Charcoal.....13.81
Dextrin.....0.95

Blue strobe rocket propellant

Source: Greg Gallacci <psygreg@u.washington.edu

Comments: The GE silicone II is noted for having an ammonia-like odor, where the GE silicones smell more like vinegar. The dimensions of the rocket made with this propellant were 1 1/8 inch ID, with a 1/2 inch core.

Preparation: Mix the copper oxide, PVC and silicone first, in a plastic bag. Then mix in the ammonium perchlorate. The stuff is said to be somewhat crumbly, and presses well.

Ammonium perchlorate.....63
Silicone II.....22
Copper(II)oxide.....10
PVC.....5

Chapter 2: Fountain, gerb and bengal fire compositions

Fountain #1

Source: rec.pyrotechnics

Comments:

Preparation:

Barium nitrate.....	45
Potassium nitrate.....	5
Meal powder.....	5
Aluminum.....	45

Fountain #2

Source: rec.pyrotechnics

Comments:

Preparation:

Meal powder.....	72
Potassium nitrate.....	7
Charcoal.....	7
Dark Aluminum.....	7
Aluminum (-80/+120).....	7

Fountain #3

Source: rec.pyrotechnics. Posted by Tom Perigrin <tip@lead.aichem.arizona.edu

Comments:

Preparation: Charcoal, sulfur and potassium nitrate are ball milled and very fine. Iron is medium coarse. After mixing (by diaper method), add an equal weight of coarse meal powder (about 1Fg to 2Fg equivalent), and mix that in too.

Potassium nitrate.....	50
Charcoal.....	10
Sulfur.....	15
Iron.....	25

Fountain #4

Source: Shimizu[1], page 127

Comments: This mixture was used in the fountains on the cover of the book. The metal powder can be either aluminum, magnalium or titanium.

Preparation:

Black powder, finely powdered.....	70
Pine charcoal.....	4
Metal powder.....	26

Fountain #5

Source: Homepage of Tom Peregrin <tip@lead.aichem.arizona.edu

Comments:

Preparation:

Potassium nitrate.....	24
Charcoal.....	4
Sulfur.....	4
Iron.....	10

Fountain #6

Source: Homepage of Tom Peregrin <tip@lead.aichem.arizona.edu

Comments:

Preparation:

Potassium nitrate.....	2
------------------------	---

Charcoal.....	41
Sulfur.....	1
Iron.....	1
Meal Powder.....	6

Fountain #7

Source: Homepage of Tom Peregrin <tip@lead.aichem.arizona.edu

Comments:

Preparation:

Potassium nitrate.....	2
Charcoal.....	4
Iron.....	2
Meal Powder.....	4

Fountain #8

Source: Homepage of Tom Peregrin <tip@lead.aichem.arizona.edu

Comments:

Preparation:

Potassium nitrate.....	8
Sulfur.....	3
Sb ₂ S ₃	1
Meal Powder.....	2

Fountain #9

Source: Homepage of Tom Peregrin <tip@lead.aichem.arizona.edu

Comments:

Preparation:

Sb ₂ S ₃	8
Aluminum.....	4
Meal Powder.....	40

Fountain #10

Source: Homepage of Tom Peregrin <tip@lead.aichem.arizona.edu

Comments:

Preparation:

Sb ₂ S ₃	9
Dextrin.....	4
Sodium oxalate.....	6
Meal Powder.....	40

Fountain #11

Source: Homepage of Tom Peregrin <tip@lead.aichem.arizona.edu

Comments:

Preparation:

Potassium nitrate.....	3
Charcoal.....	1
Sulfur.....	1
Aluminum.....	1
Meal powder.....	2

Blue fountain

Source: rec.pyrotechnics, posted by EFFECTS <effects@aol.com

Comments:

Preparation: Granulate the mixture with a small amount of alcohol. Let dry and press into tubes. Very slowly burning mixture. Don't substitute shellac with red gum.

Ammonium perchlorate.....7
Stearin.....2
Copper(II)oxide.....1
Shellac.....0.5

Gerb #1

Source: rec.pyrotechnics

Comments:

Preparation:

Meal powder.....73
Iron (60 mesh).....27

Gerb #2

Source: rec.pyrotechnics

Comments:

Preparation: The iron must be treated with linseed or tung oil.

Meal powder.....4
Charcoal fines.....1
Steel fillings.....2

Bengal fire #1

Source: Chemical abstracts[14] 122, 595944

Comments: Improved color, larger sparks and increased scatter radius for sparks.

Preparation:

Zr.....2-5
Cast iron shot.....18-23
Fe powder.....20-25
Al powder.....2-5
Corn dextrin binder.....3-6
Potato starch binder.....0.5-1.5
Barium nitrate.....balance

Bengal fire #2

Source: Chemical abstracts[14] 122, 59595

Comments: Increased combustion time

Preparation:

di-Buphtalate.....3-5
Fe-powder.....20-29
Al-powder.....4-7
Polyvinylbutyral binder.....11-17
NH4NO3 inhibitor.....1-4
Ammonium perchlorate.....balance

Green bengal fire #1

Source: rec.pyrotechnics. Posted by Sweden <sweden@synchron.ct.se

Comments:

Preparation:

Barium nitrate.....80
PVC.....10
Red Gum.....10

Green Bengal fire #2

Source: "Mengen en Roeren"[6] , page 223

Comments:

Preparation:

Barium chlorate.....90
Shellac.....10

Green Bengal fire #3

Source: "Mengen en Roeren"[6] , page 223

Comments:

Preparation:

Barium chlorate.....23
Barium nitrate.....59
Potassium chlorate.....6
Shellac.....10
Stearic acid.....1

Green Bengal fire #4

Source: "Mengen en Roeren"[6] , page 223.

Comments: Burns nice and slowly leaving little residue, but not with a green color.

Preparation:

Barium nitrate.....6
Potassium nitrate.....3
Sulfur.....2

Blue Bengal fire #1

Source: "Mengen en Roeren"[6] , page 223.

Comments: This is a dangerous mixture since it contains a copperammonium complex and a chlorate.

Preparation:

Potassium chlorate.....6
Copper ammonium sulphate.....8
Shellac.....1
Willow charcoal.....2

Blue Bengal fire #2

Source: "Mengen en Roeren"[6] , page 223.

Comments: Burns moderately fast with a blueish-white color.

Preparation:

Potassium chlorate.....40
Copper sulphate.....8
Colophonium.....6

Chapter 3: Colored fire compositions, flares and torches

Blue fire composition #1

Source: rec.pyrotechnics. post by Pierre de Reuck <pierre@icon.co.za

Comments: Dangerous mixture, since it contains both a nitrate and a chlorate with a copper ammonium compound and also a combination of chlorate with sulfur.

Preparation:

Sulfur.....	15
Potassium sulphate.....	15
Cupric ammonia sulphate.....	15
Potassium nitrate.....	27
Potassium chlorate.....	28

Blue fire composition #2

Source: rec.pyrotechnics

Comments:

Preparation:

Copper ammonium chloride.....	5
Potassium perchlorate.....	24
Stearin.....	2
Asphaltum.....	1

Blue fire composition #3

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains sulfur and a chlorate.

Preparation:

Potassium chlorate.....	7
Copper(II)sulfide.....	2
Sulfur.....	4

Blue fire composition #4

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments:

Preparation:

Potassium nitrate.....	1
Copper(II)oxide.....	1
Hg ₂ Cl ₂	1
Charcoal.....	1

Blue fire composition #5

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments:

Preparation:

Potassium nitrate.....	12
Sulfur.....	4
Sb ₂ S ₃	2

Blue fire composition #6

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation:

Potassium nitrate.....7.5
Potassium chlorate.....14
Potassium sulfate.....7
Sulfur.....7

Blue fire composition #7

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation:

Potassium chlorate.....8
Copper sulfate.....5
Shellac powder.....3
Sulfur.....7
Hg₂Cl₂.....4

Red fire composition #1

Source: "Mengen en Roeren"[6], page 223.

Comments: Burns at a moderate rate with a nice deep red color.

Preparation:

Strontium nitrate.....66
Potassium chlorate.....25
Powdered shellac.....9

Red fire composition #2

Source: "Mengen en Roeren"[6], page 223.

Comments:

Preparation:

Strontium carbonate.....16
Potassium chlorate.....72
Powdered shellac.....12

Red fire composition #3

Source: "Mengen en Roeren"[6], page 223.

Comments:

Preparation:

Strontium nitrate.....4
Potassium chlorate.....12
Strontium carbonate.....3
Kauri powder.....5

Red fire composition #4

Source: "Mengen en Roeren"[6], page 223.

Comments:

Preparation: The vaseline/wood dust mixture is prepared by melting 6 parts vaseline and mixing in 8 parts wood dust.

Potassium perchlorate.....9
Strontium nitrate.....40
Sulfur.....11

Colophonium.....	1
Sugar.....	1
Antimony.....	1/2
Vaseline/Wood dust.....	20

Red fire composition #5

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation:

Potassium chlorate.....	2
Strontium nitrate.....	5
Charcoal.....	1
Sulfur.....	1

Red fire composition #6

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation:

Potassium chlorate.....	1
Calcium carbonate.....	11
Strontium nitrate.....	11
Sulfur.....	4
Charcoal.....	1

Red fire composition #7

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments:

Preparation:

Potassium chlorate.....	29
Strontium carbonate.....	6
Orange shellac powder.....	5

Red fire composition #8

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments:

Preparation:

Strontium nitrate.....	4
Orange shellac powder.....	1

Red fire composition #9

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation:

Strontium nitrate.....	4
Potassium chlorate.....	13
Hg ₂ Cl ₂	4
Sulfur.....	2.5
Shellac powder.....	1
Charcoal.....	1

Green fire composition #1

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation:

Barium nitrate.....7
Potassium chlorate.....3
Sulfur.....2

Green fire composition #2

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation:

Barium nitrate.....3
Potassium chlorate.....8
Sulfur.....3

Green fire composition #3

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments:

Preparation:

Barium chlorate.....9
Orange shellac powder.....1

Green fire composition #4

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Burns at a moderate rate with a greenish white flame. Not very convincing green.

Preparation:

Barium nitrate.....3
Potassium chlorate.....4
Orange shellac powder.....1

Green fire composition #5

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation:

Barium nitrate.....18
Potassium chlorate.....9
Sulfur.....4.5
Shellac powder.....1.5
Hg₂Cl₂.....3
Charcoal.....1.5

White fire composition #1

Source: "Mengen en Roeren"[6], page 223.

Comments:

Preparation:

Potassium nitrate.....24
Sulfur.....7
Charcoal.....1

White fire composition #2

Source: "Mengen en Roeren"[6], page 223.

Comments:

Preparation:

Potassium nitrate.....7
Sulfur.....2
Powdered antimony.....1

White fire composition #3

Source: "Mengen en Roeren"[6], page 223.

Comments:

Preparation:

Potassium perchlorate.....7
Barium nitrate.....34
Sulfur.....7
Powderd Aluminum.....10

White fire composition #1

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments:

Preparation:

Potassium nitrate.....6
Sb₂S₃.....1
Sulfur.....1

White fire composition #2

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments:

Preparation:

Potassium nitrate.....24
Charcoal.....1
Sulfur.....1

Yellow fire composition #1

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments:

Preparation:

Potassium nitrate.....4
Sulfur.....1
Charcoal.....2
Sodium chloride.....3

Yellow fire composition #2

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation:

Potassium chlorate.....5
Sodium oxalate.....2

Potassium nitrate.....	1
Charcoal.....	2
Sulfur.....	1

Yellow fire composition #3

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation:

Potassium chlorate.....	9
Sodium oxalate.....	3
Sulfur.....	3
Shellac.....	1.5

Yellow fire composition #4

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation:

Potassium chlorate.....	8
Sulfur.....	2
Sodium carbonate.....	3

Purple fire composition

Source: rec.pyrotechnics. Composition from "Magic With Chemistry"[7], chapter "colored fires"

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation:

Copper sulfate.....	1
Potassium chlorate.....	1
Sulfur.....	1

Magnesium flare #1

Source: rec.pyrotechnics. Composition from "Fireworks, Principles and Practice"[2]

Comments:

Preparation: Magnesium is corroded by some nitrates when damp. It is common practice to coat the magnesium before use. about 4% linseed oil, or some potassium dichromate can be used for that purpose.

Barium nitrate.....	22.5
PVC.....	13
Magnesium (grade 0).....	35
Potassium perchlorate.....	22.5
Polyester.....	5

Magnesium flare #2

Source: Kirk-Othmer technical encyclopedia[8], chapter 'Explosives and Propellants'.

Comments: Heat of reaction: 6.134 kJ/g, Gas volume: 74 cm³/g, ignition temperature: 640°C, impact sensitivity test: 19% of TNT

Preparation:

Sodium nitrate.....	38
Magnesium.....	50
Laminac.....	5

Green torch #1

Source: rec.pyrotechnics

Comments: Note that calomel is a very toxic compound.

Preparation:

Barium chlorate.....5
Barium nitrate.....4
Shellac.....1
Calomel.....2

Green torch #2

Source: rec.pyrotechnics

Comments:

Preparation:

Barium nitrate.....5
potassium perchlorate.....6
K.D. Gum.....2
Sulfur.....3

Green torch #3

Source: rec.pyrotechnics

Comments: Dangerous mixture, since it contains both an ammonium compound and a chlorate.

Preparation:

Barium nitrate.....40
Potassium chlorate1
K.D. Gum.....6
Ammonium chloride.....1

Blue torch #1

Source: rec.pyrotechnics

Comments: Note that calomel and Paris green are both very toxic compounds.

Preparation:

Potassium perchlorate.....5
Copper acetoarsenite (Paris Green).....2
Dextrin.....1
Calomel.....1

Blue torch #2

Source: rec.pyrotechnics

Comments: This mixture is incompatible with nitrates and chlorates due to the presence of a copper-ammonium compound.

Preparation: 'Sugar of milk' is lactose.

Potassium perchlorate.....24
Copper ammonium sulfate.....6
Sugar of milk.....2
Sulfur.....9

Blue torch #3

Source: rec.pyrotechnics

Comments: This mixture is incompatible with nitrates and chlorates due to the presence of a copper-ammonium compound.

Preparation:

Potassium perchlorate.....	24
Copper ammonium chloride.....	6
Stearin.....	2
Asphaltum.....	1

Purple torch #1

Source: rec.pyrotechnics

Comments: Note that calomel is very toxic.

Preparation:

Strontium nitrate.....	7
Potassium perchlorate.....	9
Copper(II)oxide.....	6
Calomel.....	3
Sulfur.....	5

Amber torch

Source: rec.pyrotechnics

Comments:

Preparation:

Strontium nitrate.....	36
Sodium oxalate.....	8
Shellac.....	5
Sulfur.....	3
Potassium perchlorate.....	10

Aluminum torch

Source: rec.pyrotechnics

Comments:

Preparation:

potassium perchlorate.....	13
Fine aluminum powder.....	6
Flake Aluminum.....	5
Dextrin or lycopodium.....	1

Red and aluminum torch #1

Source: rec.pyrotechnics

Comments: The composition is a modification of the 'Aluminum torch'. Suggested dimensions for the torch are 2.22 cm diameter and 45 cm length.

Preparation: Before ramming, this formula should be moistened with a solution of 1 part shellac in 16 parts alcohol and 1 part of this solution used to every 36 parts of composition. As this mixture is somewhat difficult to ignite it is necessary to scoop out a little from the top of the torch and replace it with a starting fire composition. Meal powder can be used for that purpose.

Strontium nitrate.....	35
Potassium perchlorate.....	7
Shellac.....	4
Coarse flake Aluminum.....	4
Lycopodium.....	1

Red and aluminum torch #2

Source: rec.pyrotechnics

Comments: The composition is a modification of the 'Aluminum torch'. Suggested dimensions for the torch are 2.22cm diameter and 45cm length.

Preparation: Before ramming, this formula should be moistened with a solution of 1 part shellac in 16 parts alcohol and 1 part of this solution used to every 36 parts of composition. As this mixture is somewhat difficult to ignite it is necessary to scoop out a little from the top of the torch and replace it with a starting fire composition. Meal powder can be used for that purpose.

Strontium nitrate.....13
Sulfur.....3
Mixed Aluminum.....3

Extra bright torch

Source: rec.pyrotechnics

Comments: According to the original text: "An aluminum torch of heretofore unheard of brilliance and giving an illumination, in the 2.54cm size, of what is said to be 100000 candlepower". Testing with paint grade aluminum revealed that it burns very bright indeed at a steady slow burnrate and with little residue. It is easily pressed in tubes.

Preparation: Rub the Vaseline into the barium nitrate. Mix the sulfur and the aluminum separately. Then mix it with the barium nitrate/vaseline mixture. A starting fire mixture is required for ignition. The 'starting fire #1' composition can be used for that purpose.

Barium nitrate.....38
Mixed Aluminum.....9
Sulfur.....2
Vaseline.....1

Chapter 4: Sparkler compositions

Sparkler #1

Source: rec.pyrotechnics

Comments:

Preparation:

Potassium perchlorate.....40
Mixed titanium fines.....40
Dextrin.....18
Propyl guar.....2

Sparkler #2

Source: rec.pyrotechnics

Comments:

Preparation:

Potassium nitrate.....14
Sulfur.....3
Charcoal.....3
Aluminum.....2
Binder.....qs

Sparkler #3

Source: Chemical abstracts[14] 122, 59596

Comments: Better visual effect, better spark lifting altitude. lower combustion rate, and better safety.

Preparation:

Charcoal.....	5-20
Nitroguanidine.....	10-20
Ti or Mg/Al alloy powder (as spark forming component).....	10-20
Fe-powder (spark forming).....	10-30
Potassium nitrate.....	balance

Sparkler #4

Source: rec.pyrotechnics, posted by Footleg <chm5pf@sun.leeds.ac.uk

Comments:

Preparation:

Potassium perchlorate.....	60
Aluminum.....	30
Dextrin.....	10

Sparkler #5

Source: rec.pyrotechnics, posted by Footleg <chm5pf@sun.leeds.ac.uk

Comments:

Preparation: Dextrin binder can probably be used.

Potassium nitrate.....	14
Sulfur.....	3
Charcoal.....	3
Aluminum.....	2

Sparkler #6

Source: rec.pyrotechnics, posted by Footleg <chm5pf@sun.leeds.ac.uk

Comments:

Preparation:

Barium chlorate.....	16
Aluminum flitter.....	24
Shellac.....	3

Sparkler #7

Source: rec.pyrotechnics, posted by Footleg <chm5pf@sun.leeds.ac.uk

Comments:

Preparation:

Strontium nitrate.....	5
Shellac.....	1

Sparkler #8

Source: rec.pyrotechnics, posted by Footleg <chm5pf@sun.leeds.ac.uk

Comments:

Preparation:

Potassium perchlorate.....	50
Fine Aluminum.....	35
Dextrin.....	15

Sparkler #9

Source: rec.pyrotechnics, posted by Footleg <chm5pf@sun.leeds.ac.uk

Comments:

Preparation:

Potassium nitrate.....	7
Sulfur.....	2
Charcoal.....	4
Aluminum.....	3

Sparkler #10

Source: rec.pyrotechnics. Original by Bruce Snowden, post by Sweden <sweden@synchron.ct.se.

Comments: The composition burns very fast and explosively if one doesn't pay extreme attention towards the diameter of the sparkler. It is found that if the comp is thinner than 1.8 mm then the propagation stops. If the diameter is more than 2.0 mm the burning is too fast, sending sparks all the way down to the ground. Another severe problem is keeping the ingredients mixed in the suspension. The Ti has a very strong tendency of ending up in the bottom of the test tube, making a plug. Another problem is that after the first dipping and subsequent drying, the second (and last) dipping has to be performed very, very fast or else the first dipping is spoiled, hence the bound dextrin is redissolved. Using coarser perchlorate, finer titanium and making the dipping mixture thicker (by using less solvent) may solve these problems.

Preparation:

potassium perchlorate.....	47
Titanium.....	47
Dextrin.....	6

Sparkler #11

Source: rec.pyrotechnics. Inventor of this composition is Bruce Snowden. posted by Sweden <sweden@synchron.ct.se

Comments:

Preparation: The aluminum is probably supposed to be atomized, but experimentation is required.

Potassium nitrate.....	14
Sulfur.....	3
Charcoal.....	3
Aluminum.....	2
Binder.....	qs

Sparkler #12

Source: rec.pyrotechnics. Original is by Bruce Snowden. Posted by Sweden <sweden@synchron.ct.se

Comments:

Preparation: Guar gum comes from the seeds of the legume *Cyanopsis Psoralioides*. It should be possible to substitute red gum.

Potassium perchlorate.....	40
Mixed titanium fines.....	40
Dextrin.....	18
Propyl guar.....	2

Sparkler #13

Source: "Mengen en Roeren"[6], page 224.

Comments:

Preparation: Mix the composition with a 10% dextrin solution in water, and dip iron wire or wood in the moist composition. Adding 500 parts strontium nitrate will produce a red color, adding 60 parts barium nitrate will produce a green color.

Potassium chlorate.....	300
Aluminum granules.....	60
Charcoal.....	2

Sparkler #14

Source: rec.pyrotechnics. Posted by Tom137 <tom137@aol.com>. Composition from Weingart[5], p. 190.

Comments:

Preparation:

Potassium perchlorate.....	10
Aluminum, finely powdered.....	7
Dextrin.....	3
Water.....	20

Chapter 5: Smoke Compositions

White smoke

Source: "Mengen en Roeren"[6], page 224.

Comments:

Preparation:

Potassium nitrate.....	4
Charcoal.....	5
Sulfur.....	10
Wood dust.....	3

Red smoke

Source: "Mengen en Roeren"[6], page 224.

Comments:

Preparation:

Potassium chlorate.....	15
para-nitroaniline red.....	65
Lactose.....	20

Green smoke

Source: "Mengen en Roeren"[6], page 224.

Comments:

Preparation:

Synthetic indigo.....	26
Auramine (yellow).....	15
Potassium chlorate.....	35
Lactose.....	26

Smoke composition #1

Source: rec.pyrotechnics

Comments: Different sources mention different compositions. The most often mentioned one is given here.

Preparation: The mixture is most successful when prepared by melting the sugar and potassium nitrate together on low heat, but this requires good stirring, and there is a risk of accidental ignition. The molten mixture can be poured in cardboard containers and a fuse inserted while the mixture solidifies.

Potassium nitrate.....	50
Sugar.....	50

Smoke composition #2

Source: rec.pyrotechnics (composition is an U.S. military smoke composition)

Comments: The mixture is difficult to ignite. Hexachloroethane is poisonous, and can be replaced by 72 parts PVC.

This, however, makes the mixture yet harder to ignite. The zinc oxide can be replaced by titanium dioxide (2 parts ZnO replaced by 1 part TiO₂). The smoke is slightly irritating and not suitable for indoor use.

Preparation:

Zinc oxide.....45
Hexachloroethane.....45
Aluminum.....10

Smoke composition #3

Source: "Spelen met vuur"[9]

Comments:

Preparation:

Zinc powder.....35
CCl₄.....41
Zinc oxide.....20
Diatomeous earth.....5

Smoke composition #4

Source: "Spelen met vuur"[9]

Comments:

Preparation:

Zinc powder.....25
CCl₄.....50
Zinc oxide.....20
Diatomeous earth.....5

Smoke composition #5

Source: Kirk-Otthmer technical encyclopedia[8], chapter 'Explosives and Propellants'.

Comments: Heat of reaction: 2.579 kJ/g, Gas volume: 62 cm³/g, ignition temperature: 475°C, impact sensitivity test: 15% of TNT

Preparation:

Zinc.....69
Potassium perchlorate.....19
Hexachlorobenzene.....12

Chapter 6: Flash, burst charges and whistle mix

Flash #1

Source: Lancaster[2], listed as 'Thunder #1'.

Comments: The sulfur can be replaced by antimony trisulfide and the sound of a salute made with this composition will change very little.

Preparation:

potassium perchlorate.....50
Aluminum.....23
sulfur.....27

Flash #2

Source: rec.pyrotechnics, Listed as 'Ellern #121' in Ellern [4].

Comments:

Preparation:

potassium perchlorate.....70
Aluminum (dark pyro).....30

Flash #3

Source: rec.pyrotechnics

Comments: Larger percentage of aluminum results in a stronger flash. This composition is slightly less sensitive than the usual perchlorate mixtures which also contain sulfur.

Preparation:

Potassium perchlorate.....65...70%
Aluminum powder.....rest (up to 100%)

Flash #4

Source: rec.pyrotechnics. Post by Mark Anthony Messina <messim3@hall103.its.rpi.edu

Comments:

Preparation:

Potassium perchlorate.....3
Aluminum, 400 mesh.....3
Sulfur.....1

Flash #5

Source: rec.pyrotechnics. Post by Bill Nelson <billn@hpcvaac.cv.hp.com. Composition from Allen's book.

Comments: This is a relatively safe flash composition. Burns with a brilliant white light in an open tube, or when unconfined. When well confined, it produces a loud, low pitched report and a short but intense flash.

Preparation:

Potassium nitrate.....50
Sulfur.....30
Aluminum.....20

Flash #6

Source: rec.pyrotechnics. Post by Patrick Arnold <pcats@cryton.demon.co.uk

Comments: Can be ignited by a fairly low temperature flame, and produces a greenish flash when magnesium is used. Burns very fast, and produces a loud report even in an open container.

Preparation:

Magnesium or Aluminum.....1
Barium sulfate.....1

Flash #7

Source: rec.pyrotechnics. Post by Barrie Hiern <ilikecpu@nevada.edu

Comments: Relatively insensitive.

Preparation:

Barium nitrate.....4
Alumium (fine mesh).....2
sulfur.....1

Flash #8

Source: PML mailing list, post by Bill Ofca <ofca@mhv.net

Comments:

Preparation: Dampen the mix lightly with water and mix thoroughly such that the material is crumbly but then packs

tightly into a ball. If it is at all greasy feeling or mushy, there is way too much water. Save some dry mix on the side just in case it becomes too wet during the dampening. Granulate the damp comp by rubbing the packed ball over a 20 mesh screen. Do not use any screens larger than 20 mesh. If the screen plugs, the comp is too damp. Add more dry comp and thoughtly mix in. After drying the granulated powder, it can be used in flash bags. About 3 to 5 grams works well in a 3 inch shell. Experimentation is needed to adjust the amount of burst for good results with different stars and shell construction. This powder can also be used ungranulated, in a central flash bag, in larger shells.

Potassium nitrate.....	3
Potassium perchlorate.....	3
Dark aluminum (USB 809).....	3
Barium nitrate.....	1
Antimony sulfide (CN).....	1
Sulfur.....	1
Dextrin.....	1/2

Flash #9

Source: rec.pyrotechnics. Post by Wouter Visser <wvisser@stud.chem.ruu.nl

Comments: The use of permanganate in pyrotechnic compositions is not recommended, since it is unstable and will decompose over time. Also, like all flash mixtures, this mixture is quite sensitive and powerfull. Great care should be taken when handling this mixture.

Preparation:

Potassium permanganate.....	12
Aluminum.....	7
Sulfur.....	10

Flash #10

Source: Shimizu[1], Page 44

Comments: Listed as a report formulation.

Preparation:

Potassium perchlorate.....	80
Aluminum.....	27
Sulfur.....	3

Flash #11

Source: Shimizu[1], Page 44

Comments: Listed as a report formulation. Shimizu states that this composition produces the loudest report obtainable with a pottasium perchlorate/aluminum/sulfur composition.

Preparation:

Potassium perchlorate.....	64
Aluminum.....	23
Sulfur.....	13

Flash #12

Source: Shimizu[1]. Page 44

Comments: Listed as a report formulation. This composition produces slightly less noise than "Flash #11", but is safer to handle than similar compositions containing sulfur.

Preparation:

Potassium perchlorate.....	72
Aluminum.....	28

Flash #13

Source: Lancaster[2], page 120

Comments: Listed as a report formulation

Preparation:

Barium nitrate.....68
aluminum, dark pyro.....23
Sulfur.....9

H3 Bursting charge

Source: Shimizu[1]. Page 207

Comments: This energetic burst charge is used for small diameter shells (2...3 inch), since it makes a large and symmetrical burst possible. Besides the composition below, a ratio of chlorate to hemp coal of 10:3 is also popular. The sensitivity of this mixture to shock and friction is unexpectedly low, as long as the composition does not come into contact with sulfur or sulfur compounds.

Preparation:

Potassium chlorate.....75
Hemp coal (or Paulownia coal).....25
Glutinous rice starch.....+2%

Potassium perchlorate bursting charge #1

Source: Shimizu[1]. Page 208. Listed as 'KP burst charge'

Comments: This energetic burst charge can be used for small shells, but is unsuitable for the smallest diameters (2...3 inch). It is much safer to handle than the H3 bursting charge since it contains no chlorates.

Preparation:

Potassium perchlorate.....70
Hemp coal (or Paulownia coal).....18
Sulfur.....12
Glutinous rice starch.....+2%

Potassium perchlorate bursting charge #2

Source: Shimizu[1]. Page 210

Comments: Shimizu lists this composition as 'burst charge No. 5'. This composition's sensitivity is quite low, although higher than that of black powder. The explosive force of this composition is lower than that of the 'Potassium perchlorate bursting charge #1'. This burst charge is often used in shells of middle and large diameter (6...10 inch).

Preparation:

Potassium perchlorate.....70
Hemp coal (or Paulownia coal).....30
Glutinous rice starch.....+2%

Potassium perchlorate bursting charge #3

Source: Shimizu[1]. Page 210

Comments: Shimizu lists this composition as 'burst charge No. 44'. The potassium bichromate catalyses the decomposition of the potassium perchlorate. This composition's sensitivity is quite low, although higher than that of black powder. The explosive force of this composition is lower than that of the 'Potassium perchlorate bursting charge #1'. This burst charge is often used in shells of middle and large diameter (6...10 inch).

Preparation:

Potassium perchlorate.....70
Hemp coal (or Paulownia coal).....30
Potassium bichromate.....5
Glutinous rice starch.....+2%

Potassium perchlorate bursting charge #4

Source: Shimizu[1]. Page 210

Comments: Shimizu lists this composition as 'burst charge No. 46'. The potassium bichromate catalyses the decomposition of the potassium perchlorate. This composition's sensitivity is quite low, although higher than that of black powder. The explosive force of this composition is higher than that of the 'Potassium perchlorate bursting charge #1', especially when the particle size of the carbon is small.

Preparation:

Potassium perchlorate.....	70
Hemp coal (or Paulownia coal).....	30
Lampblack.....	25
Potassium bichromate.....	+5%
Glutinous rice starch.....	+2%

Smokeless flash powder

Source: "Mengen en Roeren"[6], page 224

Comments:

Preparation:

Zirconium.....	28
Zirconium hydride.....	7
Magnesium.....	7
Barium nitrate.....	30
Barium oxyde.....	25
Rice starch.....	5

Photoflash

Source: Kirk-Othmer chemical encyclopedia[8]. Chapter 'Explosives and Propellants'.

Comments: Heat of reaction: 8.989 kJ/g, Gas volume: 15 cm³/g, ignition temperature: 700°C, impact sensitivity test: 26% of TNT. half a pound of this flash delivers 120 million candlepowder. It is used in the M120A1 and M112A1 flare cartdriges.

Preparation:

Aluminum (20 micron; atomized).....	40
Potassium perchlorate (24 micron).....	30
Barium nitrate (150 micron).....	30

Purple Flash

Source: rec.pyrotechnics

Comments:

Preparation:

Magnesium.....	10
Potassium perchlorate.....	10
Cupric oxide.....	3
Strontium nitrate.....	3
PVC.....	1

Yellow flash

Source: "Spelen met vuur"[9]

Comments:

Preparation:

Magnesium.....	1
Sodium nitrate.....	6

Green flash

Source: rec.pyrotechnics

Comments:

Preparation:

potassium perchlorate.....6
barium nitrate.....3
Aluminum powder.....5

Whistle mix #1

Source: rec.pyrotechnics. Composition from Ellern[4].

Comments:

Preparation:

Potassium perchlorate.....72.5
Sodium salicylate.....27.5

Whistle mix #2

Source: rec.pyrotechnics. Composition from Ellern[4].

Comments:

Preparation:

Potassium nitrate.....30
Potassium dinotrophenate.....70

Whistle mix #3

Source: rec.pyrotechnics. Composition from Ellern[4] and Shimizu[1].

Comments:

Preparation:

Potassium perchlorate.....70
Sodium benzoate.....30

Whistle mix #4

Source: rec.pyrotechnics. Composition from Oztap

Comments:

Preparation:

Potassium chlorate.....40
Sodium chlorate.....10
Potassium nitrate.....30
Sodium salicylate.....10
Paraffin oil.....10
Ferric oxide.....+0.2

Whistle mix #5

Source: rec.pyrotechnics. Composition from Lancaster[2].

Comments: This mixture is quite sensitive to friction and shock.

Preparation:

Potassium chlorate.....75
Gallic acid.....25

Chapter 7: Miscellaneous compositions

Black powder

Source: Various sources

Comments: Two methods of preparation exist, the precipitation or CIA method, and the ball milling method. The latter produces slightly superior results. Special attention should be given to the charcoal used. Charcoal is best obtained by pyrolysis of soft-wood. Preferred types of wood are willow, grapevine and laurel. In general all young, thin soft-woods without hard knots can be used. Although several different compositions are used for several purposes, the composition given here is used most often:

Preparation: Merely mixing the charcoal, sulfur and potassium nitrate by hand does not make black powder. They must really be incorporated into each other. This can be done by ball milling or by the salting out ('CIA') method. A detailed description of the process can be found in many books.

Potassium nitrate.....	75
Charcoal.....	15
Sulfur.....	10

Yellow powder

Source: rec.pyrotechnics, post by The Silent Observer <silent1@ix.netcom.com>. It comes from a text of 'Samuel Guthrie' written in 1831. More about this mixture can be found in Davis[10], page 30 and 31.

Comments: It is sometimes called "Fulminating powder". The mixture burns three times quicker than common black powder.

Preparation: The compounds are sometimes molten together, which appears to be a very dangerous operation.

Potassium nitrate.....	3
Potassium carbonate.....	2
Sulfur.....	1

Priming composition #1

Source: rec.pyrotechnics

Comments:

Preparation:

Barium nitrate.....	4
Potassium nitrate.....	3
Sulfur.....	1
Shellac.....	1

Priming composition #2

Source: "Spelen met vuur"[9]

Comments:

Preparation:

Potassium permanganate.....	54
Powdered iron.....	47

Priming composition #3

Source:

Comments: Suitable for priming most stars. Chlorate stars or stars containing ammonium compounds should never be primed with this composition. It can be stored in small plastic containers.

Preparation:

Potassium nitrate, fine, sieved.....	75
Sulfur, fine (preferably flour).....	10

Charcoal, fine, sieved.....15

Priming composition #4

Source:

Comments: Suitable for priming stars. Aluminum and manganese dioxide aid in ignition, but are not necessary.

Preparation:

Potassium perchlorate.....80
Charcoal, fine.....15
Red gum.....4
Manganese dioxide (optional)9
Aluminum, (fine flake or pyro grade; optional)....4
Dextrin.....2

Priming composition #5

Source:

Comments: This type of prime helps reduce the friction and impact sensitivity of chlorate stars which is especially important when shells fire from the mortar and experience set-back or "kick" from lift acceleration.

Preparation:

Potassium perchlorate.....68
Charcoal, air float.....20
Silicon or Aluminum.....9
Dextrin.....3

Priming composition #6

Source: PML, post by J. Humby <jhumby@iee.org

Comments: This prime is safe to use with chlorate stars and gives a much better color than a black powder prime. The difference is most noticeable on red stars which tend to a dark salmon color when primed with black powder.

Preparation: Dissolve the potassium nitrate in hot water and mix with the charcoal.

Potassium chlorate.....52
Potassium nitrate.....8
Charcoal.....30
Lampblack.....10
Binder.....+5%

Priming composition #7

Source: Shimizu[1], page 218

Comments: A standard black powder priming cannot be used with stars that contain ammonium perchlorate, since a double decomposition reaction forms the highly hygroscopic ammonium nitrate. This makes the stars unignitable. Replacing the potassium nitrate prime by this priming composition solves that problem.

Preparation:

Sodium nitrate.....80
Paulownia coal.....15
Sulfur.....5

Priming composition #8

Source: Shimizu[1], page 225. Listed as "Ignition composition for twinklers".

Comments: Used for strobe stars of ammonium perchlorate base to prevent nitrates from the outer priming to react with the ammonium perchlorate. The layer should be at least 1-2mm thick.

Preparation:

Potassium perchlorate.....74

Rosin (BL combustion agent) or Red gum.....	12
Hemp coal (or paulownia coal).....	6
Aluminum (fine flake).....	3
Potassium bichromate.....	5

Delay composition #1

Source: Kirk-Othmer technical encyclopedia[8], chapter 'Explosives and Propellants'.

Comments: Heat of reaction: 2.010 kJ/g; Gas volume: 13 cm³/g; Ignition temperature: 450°C; impact sensitivity test: 12 % of TNT.

Preparation:

Barium chromate.....	90
Boron.....	10

Delay composition #2

Source: Kirk-Othmer technical encyclopedia[8], chapter 'Explosives and Propellants'.

Comments: Heat of reaction: 2.081 kJ/g; Gas volume: 12 cm³/g; Ignition temperature: 485°C; impact sensitivity test: 23 % of TNT.

Preparation:

Barium chromate.....	60
Zirconium-nickel alloy.....	26
Potassium perchlorate.....	14

Changing Relay #1

Source: Shimizu[1], page 187

Comments: This type of composition is put between two color layers in a star to create the illusion that all the stars change their color clearly and simultaneously in spite of slight deviations in manufacture.

Preparation:

Potassium perchlorate.....	35
Potassium nitrate.....	35
Hemp coal (or Paulownia coal).....	24
Soluble glutinous rice starch.....	6

Changing Relay #2

Source: Shimizu[1], page 187

Comments: This type of composition is put between two color layers in a star to create the illusion that all the stars change their color clearly and simultaneously in spite of slight deviations in manufacture.

Preparation:

Potassium perchlorate.....	81
Red gum.....	13
Soluble glutinous rice starch.....	6

Golden rain #1

Source: "Mengen en Roeren"[6], page 224

Comments: Burns with a yellow color, and emits yellow sparks that are formed by the slowly burning lampblack.

Preparation:

Potassium nitrate.....	18
Sulfur.....	8
Lampblack.....	5

Golden rain #2

Source: "Mengen en Roeren"[6], page 224

Comments: Burns with a yellow color, and emits yellow sparks that are formed by the slowly burning lampblack and the iron filings.

Preparation:

Potassium nitrate.....	10
Sulfur.....	2
Lampblack.....	2
Fine iron filings.....	7

Fire dust

Source: Shimizu[1], page 67

Comments: The composition spreads a large amount of long lived orange fire dust particles. The lifetime of those particles depends mainly on the consistency and type of charcoal.

Preparation: The components must be intimately mixed. This can be done by dissolving the potassium nitrate in a minimum amount of boiling water, adding the charcoal and sulfur and precipitating the potassium nitrate in the form of fine particles by adding a large amount of isopropyl alcohol and cooling the solution as fast as possible to 0°C, followed by filtering and drying.

Potassium nitrate.....	58
Charcoal.....	35
Sulfur.....	7

Senko Hanabi (Japanese sparklers), sulfur based

Source: Shimizu[1], page 70

Comments: For more details on what the effect looks like and how devices can be constructed, look at §10.4, "The phenomenon of Senko-Hanabi" in Shimizu's book (on page 68). Realgar may be used instead of sulfur, see 'Senko Hanabi (Japanese sparklers), realgar based' for a realgar based formula. The realgar based formula produces larger en more beautiful sparks.

Preparation:

Potassium nitrate.....	60
Charcoal or soot.....	10-20
Sulfur.....	20-30

Senko Hanabi (Japanese sparklers), realgar based

Source: Shimizu[1], page 70

Comments: For more details on what the effect looks like and how devices can be constructed, look at §10.4, "The phenomenon of Senko-Hanabi" in Shimizu's book (on page 68). Sulfur may be used instead of realgar, see 'Senko Hanabi (Japanese sparklers), sulfur based' for a sulfur based formula. This realgar based formula produces larger en more beautiful sparks than the sulfur based formula.

Preparation:

Potassium nitrate.....	35
Charcoal or soot.....	20
Realgar.....	45

"Pharaoh Snakes"

Source: "Mengen en Roeren"[6], page 223

Comments: When lighted, this composition produces very voluminous snake-shaped ash. Mercury compounds are very poisonous, and extreme caution should be excercised during preparing and handling this composition. Wear gloves at all times, and use a fume hood.

Preparation: Instructions for making mercuric thiocyanate: 1) Dissolve 64 parts of mercuric nitrate in water, and separately dissolve 36 parts potassium thiocyanate in water. 2) Mix both solutions, and filtrate to collect the precipitate that forms upon mixing. 3) Rinse the collected precipitate 3 times with distilled water, and place it in a warm (not hot)

place to dry.

Mercuric thiocyanate.....100
 Dragant.....5
 arabic gum binder.....qs

Thermite

Source:

Comments: This composition produces an enormous amount of heat (83.7 kJ per mol of iron oxide that has reacted), molten iron and aluminum oxide. Other metal oxides can be substituted to make other thermite-like compositions that behave differently. Some may explode (like CuO with aluminum or PbO₂ with aluminum), so caution is required when experimenting with different mixtures.

Preparation:

Red iron oxide, Fe₂O₃.....3
 Aluminum.....1

Red thermit

Source: Shimizu[1], page 29

Comments: This mixture is sometimes used for priming.

Preparation:

Pb₃O₄.....80
 Ferro-silicon.....20

Electric Match

Source: PML, post by Mike Carter <pyro@primenet.com

Comments: This composition does not require the use of a bridge wire. The composition itself acts as a resistor.

Comments from the poster: "The matches fire just fine on 200 feet of #16 guage wire and a standard 12V battery two at a time. Sometimes there's a delay...I haven't tested these on the high power electric firing systems so I don't know how they fare."

Preparation: 1) Bind in water. Make CMC & Water into a mostly soupy mess. Add components into a container and mix well. 2) Dip freshly stripped wire with both conductors about 1mm or slightly less between them, evenly parallel. The longer the exposed metal on the wire, the less Ohmage the match will have. Allow to dry in vertical hanging position. Redip as necessary. I find that two dips is just fine. 3) Once the comp is dry, you will need to coat it with NC (Nitrocellulose) laquer. I find that two dips in the NC laquer is enough to keep the very brittle comp from cracking or splitting while manuevering the wire into your shell or mine or rocket motor. I normally will color the double-dippers with some Iron Oxide stirred into the NC Laquer so I have a visual that they're unsuitable for firing whistle motors. (Double Dipped tend to go BANG, and destroy the motor).

Potassium chlorate, Ball milled into a fine powder.....16
 Conductive lampblack.....3
 Magnalium (50/50), 200 mesh.....3
 Atomized aluminum, 120 mesh.....2
 Zirconium, 200 mesh (optional).....2
 CMC Binder (carboxymethylcellulose).....5

Veline's priming

Source: rec. pyrotechnics, post by Lloyd E. Sponenburgh <lloyds@fiscalinfo.com. This set of compositions was invented by Robert Veline and is used in Kosankie's 'Chemistry of Fireworks (Chemistry of color) class'.

Comments: These compositions are part of a matched set invented by Robert Veline. The compositions mix compatibly to produce a wide range of other colors. Examples are given below. The wood meal in this prime makes the stars a little 'fuzzy', making the stars much more easy to ignite. Without the wood meal prime the stars are often blown blind.

Preparation: Summary of Robert Veline's own comments: "Potassium perchlorate is a fine powder. Parlon is Hercules

brand or Superchlone brand from Ishihara co. ltd. Red gum is a fine powder. Copper(II)oxide may be substituted by copper carbonate without much change in performance. Calcium carbonate is 200 mesh, 'Whiting'. More pure forms slow the burn rate and degrade the color."

Potassium perchlorate.....	55
Charcoal, air float.....	20
Wood meal, 70 mesh.....	6
Red Iron Oxide, Fe ₂ O ₃	5
Magnalium (50/50).....	5
Potassium dichromate.....	5
Dextrin.....	4

Brilliant core coating composition

Source: Composition from Shimizu[1], page 219.

Comments: This composition can be used to prime the 'Brilliant Core' stars (see effect stars). roll the cores in this prime until they are round.

Preparation:

Potassium perchlorate.....	33
Barium nitrate.....	34
Aluminum (fine flake).....	10
Rosin (BL combustion agent).....	8
Antimony trisulfide (or sulfur).....	9
Boric acid.....	1
Soluble glutinous rice starch.....	5

Chapter 8: colored stars

Red star #1

Source: rec.pyrotechnics archive. Composition from Shimizu[1], page 215

Comments: The perchlorate can be substituted by chlorate without changing the color.

Preparation:

Potassium perchlorate.....	66
Red gum.....	13
Lampblack.....	2
Strontium carbonate.....	12
Polyvinyl chloride.....	2
Soluble Glutinous Rice Starch.....	5

Red star #2

Source:

Comments:

Preparation: Dissolve shellac in boiling ethanol, add the other ingredients and proceed as usual. The stars take unexpectedly long to dry. They can be dried in the sun or in a vacuum. Smaller stars dry faster.

Potassium chlorate.....	20
Strontium nitrate.....	60
Shellac.....	20

Red star #3

Source:

Comments:

Preparation: Dissolve shellac in boiling ethanol, and add the other ingredients.

Potassium chlorate.....	65
Strontium carbonate.....	15
Shellac.....	20

Red star #4

Source:

Comments:

Preparation: Dissolve shellac in boiling ethanol, and add the other ingredients.

Potassium perchlorate.....	44
Strontium nitrate.....	31
Red gum.....	15
Shellac (binder).....	5
PVC or saran	8 or 7

Red star #5

Source:

Comments:

Preparation: Add water. For priming "priming composition #7" from the chapter with miscellaneous compositions can be used.

Ammonium perchlorate.....	30
Potassium perchlorate.....	35
Strontium carbonate.....	18
Hexamine.....	2
Charcoal, fine.....	2
Red gum.....	16
Dextrin.....	4

Red star #6

Source: "The pyroguide" (a document found on internet)

Comments: Dangerous mixture, since it contains both sulfur and a chlorate.

Preparation: Bind with shellac dissolved in ethanol.

Potassium chlorate.....	9
Sulfur.....	2
Lampblack.....	1
Strontium nitrate.....	9

Red star #7

Source: post on rec.pyrotechnics by Tommy Hakomaki <tommy.hakomaki@mailbox.swipnet.se. Composition from an old swedish book.

Comments:

Preparation:

Potassium nitrate.....	36
Sulfur.....	30
Meal powder.....	36
Strontium nitrate.....	40
Antimony sulfide.....	5
Charcoal.....	12

Red star #8

Source: rec.pyrotechnics. Post by Andrew Krywonizka. Composition from Lancaster[2].

Comments: Produce as a cut star

Preparation:

Potassium perchlorate.....70
Strontium carbonate.....15
Red gum.....9
Charcoal 150 Mesh.....2
Dextrin.....4

Red star #9

Source: rec.pyrotechnics. Post by Andrew Krywonizka. Composition from Lancaster[2].

Comments: Produce as a pressed star

Preparation:

Strontium nitrate.....55
Magnesium.....28
PVC.....17

Red star #10

Source: PML, post by David Abate <daveab@ix.netcom.com.

Comments: Crackling stars can be made with this composition. The poster used large pistol primers (idea from Best of AFN II), coated with 70% KClO₄/30% Dark aluminum for cores, and rolled these into stars with the star mixture. The stars were hard to ignite and needed priming.

Preparation:

Potassium perchlorate.....68
Strontium carbonate.....13
Red gum.....14
Dextrin.....5

Red star #11

Source: rec.pyrotechnics archive. Composition from Shimizu[1], page 217. It's listed under the name "Red star brilliant".

Comments:

Preparation: The magnesium must be coated with linseed oil. Use an acetone or alcohol solvable binder.

Potassium perchlorate.....30
Strontium nitrate (anhydride).....20
Magnesium, 60 mesh.....30
PVC.....18
Lampblack or Paulownia coal.....2

Red star #12

Source: rec.pyrotechnics archive. Composition from Shimizu[1], page 219. It's listed under the name "Ammon red star brilliant".

Comments:

Preparation:

Ammonium perchlorate.....41
Magnesium, 60 mesh.....33.3
Red gum.....9.5
Strontium carbonate.....9.5
Potassium bichromate.....1.9
Soluble glutinous rice starch.....4.8

Green star #1

Source: Composition from Shimizu[1], page 215

Comments:

Preparation:

Barium nitrate.....28.3
Potassium Perchlorate.....47.2
Parlon.....4.7
Red Gum.....14.2
Soluble Glutinous Rice Starch.....5.6

Green star #2

Source:

Comments: A simple but nice (somewhat yellowish) green.

Preparation: Dissolve shellac in boiling ethanol.

barium nitrate.....7
potassium chlorate.....7
shellac.....2

Green star #3

Source:

Comments: The composition leaves lots of ash. Ammonium perchlorate improves it (- Green star #4).

Preparation: Mix Parlon with magnesium. Add 50 volume parts of acetone, mix well and mix in the other ingredients. If PVC is used, add the correct amount of the solution in THF to the other ingredients.

barium nitrate.....50
lab grade magnesium powder.....32
Parlon or PVC.....18

Green star #4

Source:

Comments:

Preparation: Mix Parlon with magnesium. Add 60 volume parts of acetone for Parlon, mix well and mix in the other ingredients. If PVC is used, add the correct amount of the solution in THF to the other ingredients.

barium nitrate.....56
lab grade magnesium powder.....32
Parlon or PVC17
ammonium perchlorate.....25

Green star #5

Source:

Comments: This mixture can be improved using ammonium perchlorate (Green star #6).

Preparation: Add acetone. Prime with black powder. Aluminum should be very fine, preferably dark pyro grade.

Barium nitrate.....65
Aluminum (very fine).....10
Parlon rubber.....20
Sulfur.....4
Boric acid.....2

Green star #6

Source:

Comments: Fierce burning.

Preparation: Add acetone. Prime with "Priming composition #7".

Barium nitrate.....	65
Saran.....	20
Red gum.....	3
Sulfur.....	7
Aluminum (very fine).....	10
Ammonium perchlorate.....	15
Boric acid.....	2
Dextrin.....	2

Green star #7

Source: PML, post by Charley Wilson <cwilson@celsvr.stortek.com.

Comments: Beautiful green. Direct substitution of barium nitrate with strontium nitrate produces a nice red.

Preparation: Dissolve shellac in boiling ethanol. Prime with potassium perchlorate based strobe prime

ammonium perchlorate.....	50
barium nitrate.....	35
shellac.....	15

Green star #8

Source: "The Pyroguide" (a document found on internet)

Comments:

Preparation: Bind with alcohol.

Barium chlorate.....	8
Lampblack.....	1
Shellac powder.....	1

Green star #9

Source: "The Pyroguide" (a document found on internet)

Comments:

Preparation: Bind with alcohol.

Barium nitrate.....	3
Potassium chlorate.....	4
Shellac powder.....	1
Dextrin.....	1/4

Green star #10

Source: post on rec.pyrotechnics by Tommy Hakomaki <tommy.hakomaki@mailbox.swipnet.se>. Composition from an old swedish book.

Comments:

Preparation:

Potassium nitrate.....	35
Sulfur.....	10
Mealpowder.....	40
Barium nitrate.....	50
Charcoal.....	10

Green star #11

Source: rec.pyrotechnics, post by Bill Nelson <billn@peak.org, Composition from Davis[10].

Comments: This formulation is based on one given by Clark, who's work is suspect.

Preparation:

Potassium perchlorate.....	6
Barium perchlorate.....	12
Aluminum.....	8
Dextrin.....	2
Shellac.....	1

Green star #12

Source: rec.pyrotechnics, post by Bill Nelson <billn@peak.org, Composition from "Pyrotechnica VII"[3] by JW Stone.

Comments:

Preparation:

Potassium perchlorate.....	48
Barium nitrate.....	32
Red Gum.....	14
Charcoal.....	2
Parlon.....	12
Dextrin.....	6
Sulfur.....	5

Green star #13

Source: rec.pyrotechnics, post by Bill Nelson <billn@peak.org, Composition from "Pyrotechnica VII"[3] by JW Stone.

Comments:

Preparation:

Potassium perchlorate.....	28
Barium nitrate.....	16
Red Gum.....	4
Charcoal.....	1
Parlon.....	10
Dextrin.....	3
Aluminum #809.....	5

Green star #14

Source: rec.pyrotechnics, post by Bill Nelson <billn@peak.org, Composition from "Pyrotechnica VII"[3] by T. Fish.

Comments:

Preparation:

Barium nitrate.....	65
Parlon.....	20
Pyro Aluminum.....	10
Red gum or sulfur.....	5
Boric acid.....	+2

Green star #15

Source: PML, post by Bill Ofca <ofca@csbh.mhv.net

Comments: Original name: 'Emerald green'. The mix is not very sensitive although chlorates are present.

Preparation: Dampen with 75/25 water/alcohol and cut or roll into 10mm stars. The red gum can be replaced with shellac. If shellac is used, dampen with 50/50 water alcohol.

Potassium perchlorate.....	22
Barium chlorate.....	43
Barium nitrate.....	9
Red gum.....	22

Dextrin.....4

Green star #16

Source: rec.pyrotechnics archive. Composition from Shimizu[1], page 218. It's listed under the name "Green star brilliant".

Comments:

Preparation: The magnesium must be coated with linseed oil. Use an acetone or alcohol solvable binder.

Potassium perchlorate.....16
Barium nitrate.....42
Magnesium, 60 mesh.....25
PVC.....15
Lampblack or Paulownia coal.....2

Green star #17

Source: rec.pyrotechnics archive. Composition from Shimizu[1], page 219. It's listed under the name "Ammon green star brilliant".

Comments:

Preparation: The magnesium must be coated with potassium dichromate.

Ammonium perchlorate.....41
Magnesium, 60 mesh.....33.3
Red gum.....9.5
Barium carbonate.....9.5
Potassium bichromate.....1.9
Soluble glutinous rice starch.....4.8

Blue star #1

Source: rec.pyrotechnics archive, post by LNicksch <lnicksch@aol.com> Composition from Shimizu[1], page 216. Listed under the name "blue star II"

Comments: LNicksch : "These stars burn much faster and more blue than any mix containing copper carbonate I have tried"

Preparation: Dampen with alcohol/water 70/30 to make cut or pumped stars.

Potassium perchlorate.....66.5
Red gum.....9.9
Cupric oxide.....13.4
Parlon.....5.4
Soluble Glutinous Rice Starch or Dextrin5.6 or 4.8

Blue star #2

Source:

Comments:

Preparation: Add 25 volume parts of water to dextrin and mix in the other ingredients. Use more water if necessary.

Ammonium perchlorate.....60
Sulfur.....17
Copper(II)oxide.....20
Dextrin (binder).....3
Red gum or Shellac.....6

Blue star #3

Source:

Comments:

Preparation: Mix red gum or shellac powder with Parlon. Add 50 volume parts of acetone, mix well and mix in the

other ingredients.

potassium perchlorate.....	63
copper(II)oxide.....	13
Red gum or Shellac (powdered).....	10
Parlon or PVC.....	14

Blue star #4

Source:

Comments:

Preparation:

potassium perchlorate.....	65
cuprous chloride (CuCl).....	16
sulfur.....	10
Red gum.....	7
Parlon or PVC.....	11 or 12

Blue star #5

Source:

Comments:

Preparation: Add the PVC solution to the other ingredients. Allow some THF to evaporate, form a cake 1 cm thick and allow it to dry on a plastic plate (check that it doesn't dissolve in THF!). Remove the dry cake and cut it into stars with a pair of scissors.

Ammonium perchlorate.....	63
Copper(II)oxide.....	13
Sulfur.....	10
Dextrin.....	10
PVC.....	12

Blue star #6

Source: "The Pyroguide" (a document found on internet)

Comments: Dangerous mixture since it contains both sulfur and a chlorate.

Preparation: Bind with dextrin in water.

Potassium chlorate.....	9
Copper Acetonarsenite.....	2
Mercurous chloride.....	1
Sulfur.....	2

Blue star #7

Source: "The Pyroguide" (a document found on internet)

Comments: This one is inferior to "Blue star 6". Dangerous mixture since it contains both sulfur and a chlorate.

Preparation: Bind with dextrin in water.

Potassium chlorate.....	12
Copper sulfate.....	6
Lead chloride.....	1
Sulfur.....	4

Blue star #8

Source: rec.pyrotechnics. Posted by Tommy Hakomaki <tommy.hakomaki@mailbox.swipnet.se

Comments:

Preparation:

Potassium nitrate.....	40
Sulfur.....	12
Mealpowder.....	40
Copper-ammonium nitrate.....	30
Charcoal.....	10
Rosin.....	5

Blue star #9

Source: Composition from Shimizu[1], page 216. Listed under the name 'blue star I'

Comments:

Preparation:

Potassium perchlorate.....	60.8
Red Gum.....	9.0
Basic copper carbonate.....	12.3
Parlon.....	13.1
Soluble glutinous rice starch.....	4.8

Blue star #10

Source: PML, posted by David Abate <daveab@ix.netcom.com>.

Comments: Crackling stars can be made with this composition. The poster used large pistol primers (idea from Best of AFN II), coated with 70% KClO₄/30% Dark aluminum for cores, and rolled these into stars with the star mixture. The stars were hard to ignite and needed priming. The color is a bit pale blue.

Preparation:

Potassium perchlorate.....	61
Copper carbonate.....	12
Parlon.....	13
Red gum.....	9
Dextrin.....	5

Blue star #11

Source: "Pyrotechnica #6"[3]

Comments: This composition seems just a slight modification of "Blue star #1".

Preparation:

Potassium perchlorate.....	67.3
Red gum.....	10.0
Copper oxide.....	13.6
Parlon.....	9.1
Rice starch.....	4.5

Blue star #12

Source: PML, posted by Charley Wilson <cwilson@celsvr.stortek.com>

Comments:

Preparation:

Ammonium perchlorate.....	70
Copper(II)oxide.....	15
Shellac.....	15

Blue star #13

Source: Greg Gallacci <psygreg@u.washington.edu>

Comments: Makes a bright, robins-egg blue star, with a bushy flame.

Preparation:

Potassium perchlorate.....	70
Silicone.....	10
Copper(II)oxide.....	10
PVC.....	15

Blue star #14

Source: rec.pyrotechnics. Post by Erik D. Suni <esuni@lk-hp-26.hut.fi>. Composition is a slightly modified version from a composition from "The best of AFN II"[14].

Comments:

Preparation: Moisten with water, and cut into 6 mm stars. Do not prime with meal powder. Use a potassium perchlorate based prime instead.

Potassium chlorate.....	65
Copper oxychloride.....	12.5
Lactose.....	12.5
Dextrin.....	5
Saran.....	5

Blue star #15

Source: rec.pyrotechnics, post by Greg A. Gallacci <psygreg@u.washington.edu>

Comments: Fimo is a PVC based modelling clay. The stars are brilliant blue ("Cop-lites blue"), with edges of flame tinted salmon. The stars need priming.

Preparation: Warm the Fimo slightly, to make it more mixable and mix it with the ammonium perchlorate without using solvents. Then mix in the malachite. Screen it several times and make pressed stars.

Ammonium perchlorate.....	70
Fimo.....	20
Malachite, powdered.....	10

Blue star #16

Source: rec.pyrotechnics

Comments:

Preparation:

Potassium Perchlorate.....	60
Copper Carbonate.....	20
PVC.....	15
Dextrin.....	5

Purple star #1

Source: "The Pyroguide" (a document found on internet)

Comments: Dangerous mixture since it contains both sulfur and a chlorate.

Preparation: Bind with dextrin in water. The ingredients must be very pure.

Potassium chlorate.....	36
Strontium sulfate.....	10
Copper sulfate.....	5
Lead chloride.....	2
Charcoal.....	2
Sulfur.....	12

Purple star #2

Source: "The Pyroguide" (a document found on internet)

Comments: Dangerous mixture since it contains both sulfur and a chlorate.

Preparation: Bind with dextrin in water. The ingredients must be very pure.

Potassium chlorate.....	38
Strontium carbonate.....	18
Copper chloride.....	4
Lead chloride.....	2
Sulfur.....	14

Purple star #3

Source: Composition from Shimizu[1], page 216. Listed under the name "Violet star I".

Comments:

Preparation:

Potassium perchlorate.....	61.3
Red gum.....	9.1
Basic copper carbonate.....	5.0
Strontium carbonate.....	7.4
Parlon.....	12.4
Soluble glutinous rice starch.....	4.8

Purple star #4

Source: Composition from Shimizu[1], page 216. Listed under the name "Violet star II".

Comments:

Preparation:

Potassium perchlorate.....	64.0
Red gum.....	9.5
Copper(II)oxide.....	5.2
Strontium carbonate.....	7.8
Parlon.....	8.7
Soluble glutinous rice starch.....	4.8

Yellow star #1

Source:

Comments:

Preparation: Mix dextrin with 4 volume parts of water and mix in the other ingredients.

Potassium chlorate.....	6
Sodium hydrogen carbonate.....	2
Dextrin.....	2

Yellow star #2

Source: "The Pyroguide" (a document found on internet)

Comments:

Preparation: Bind with shellac in ethanol or dextrin in water.

Potassium chlorate.....	8
Sodium oxalate.....	3
Lampblack.....	2

Yellow star #3

Source: "The Pyroguide" (a document found on internet)

Comments:

Preparation: Bind with alcohol.

Potassium chlorate.....	8
Sodium oxalate.....	4
Shellac powder.....	2
Dextrin.....	1

Yellow star #4

Source: rec.pyrotechnics, posted by Tommy Hakomaki <tommy.hakomaki@mailbox.swipnet.se.

Comments:

Preparation:

Potassium nitrate.....	48
Sulfur.....	24
Mealpowder.....	60
Charcoal.....	10
Rosin.....	2

Yellow star #5

Source: Composition from Shimizu[1], page 215.

Comments:

Preparation:

Potassium perchlorate.....	68
Red gum.....	18
Lampblack.....	2
Sodium nitrate.....	7
Soluble glutinous rice starch.....	5

Yellow star #6

Source: rec.pyrotechnics archive. Composition from Shimizu[1], page 217. It's listed under the name "Yellow star brilliant".

Comments:

Preparation: The magnesium must be coated with linseed oil. Use an acetone or alcohol solvable binder.

Potassium perchlorate.....	45
Ultramarine.....	13
Magnesium, 60 mesh.....	30
PVC.....	10
Lampblack or Paulownia coal.....	2

Yellow star #7

Source: rec.pyrotechnics archive. Composition from Shimizu[1], page 219. It's listed under the name "Ammon yellow star brilliant".

Comments:

Preparation: The magnesium must be coated with potassium dichromate.

Ammonium perchlorate.....	41
Magnesium, 60 mesh.....	33.3
Red gum.....	9.5
Ultramarine.....	9.5
Potassium bichromate.....	1.9
Soluble glutinous rice starch.....	4.8

Orange star #1

Source: "The Pyroguide" (a document found on internet)

Comments: Dangerous mixture since it contains both sulfur and a chlorate.

Preparation: Bind with alcohol.

Strontium nitrate.....	36
Sodium oxalate.....	8
Potassium chlorate.....	5
Shellac powder.....	5
Sulfur.....	3

Orange/Red star

Source: rec.pyrotechnics archive. Posted by Greg Deputy <gdep@gemstar.gemstar.com

Comments: Sculpy is a PVC based modelling clay - "FIMO" will also work, but is more difficult to mix.

Preparation:

Strontium nitrate.....	35
Potassium perchlorate.....	40
"Sculpy".....	22
Fe ₂ O ₃	2

Salmon color star

Source: rec.pyrotechnics, post by Greg A. Gallacci <psygreg@u.washington.edu

Comments: Sculpy is a PVC based modelling clay. The result is a salmon-berry (reddish-orange) color.

Preparation: Warm the sculpy slightly, to make it more mixable and mix it with the ammonium perchlorate without using solvents. Screen it several times and make pressed stars. The stars can be baked in an oven at 135°C for 20 minutes, which will result in much harder, more ignitable, more intensely colored stars. Heating the stars is not recommended though, since it could cause the stars to ignite.

Ammonium perchlorate.....	75
"Super Sculpy".....	25

White star #1

Source: rec.pyrotechnics

Comments:

Preparation:

Potassium Nitrate.....	58
Aluminum.....	40
Dextrin.....	2

White star #2

Source: rec.pyrotechnics

Comments:

Preparation:

Potassium Perchlorate.....	40
Magnesium.....	32
Sulfur.....	16
Charcoal.....	12

White star #3

Source: rec.pyrotechnics

Comments:

Preparation:

Potassium Perchlorate.....	2
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Aluminum.....1

White star #4

Source: rec.pyrotechnics

Comments:

Preparation:

Barium Nitrate.....53
Potassium Nitrate.....12
Magnesium 100-200 mesh.....28
Parlon.....7
Acetone.....qs
50/50 alcohol/water.....qs

White star #5

Source: rec.pyrotechnics

Comments:

Preparation:

Barium or Strontium Nitrate.....60
Magnesium.....20
PVC.....20

White star #6

Source: rec.pyrotechnics

Comments:

Preparation:

Potassium nitrate.....59
Sulfur.....30
Meal powder.....11

White star #7

Source: rec.pyrotechnics

Comments:

Preparation:

Potassium perchlorate.....61
Aluminum.....31
Lycopodium.....8

White star #8

Source: "The Pyroguide" (a document found on internet)

Comments: Bind with dextrin in water

Preparation:

Potassium nitrate.....6
Sulfur.....1
Antimony sulfide.....2

White star #9

Source: rec.pyrotechnics, posted by Tommy Hakomaki <tommy.hakomaki@mailbox.swipnet.se.

Comments:

Preparation:

Potassium nitrate.....	42
Sulfur.....	18
Meal powder.....	18

White star #10

Source: rec.pyrotechnics. Post by Erik D. Suni <esuni@lk-hp-26.hut.fi>. Composition from "The best of AFN II"[14].

Comments: Meal powder priming should be sufficient.

Preparation:

Potassium nitrate.....	28
Antimony sulfide.....	6
Sulfur.....	8
Dextrin.....	1.5

Brilliant white star

Source: "The Pyroguide" (a document found on internet)

Comments: Bind with dextrin in water

Preparation:

Potassium perchlorate.....	4
Aluminum dust.....	4
Dextrin.....	1

Orange star #2

Source: rec.pyrotechnics

Comments: These compositions are part of a matched set invented by Robert Veline. The compositions mix compatibly to produce a wide range of other colors. Examples are given below. The wood meal in the prime (see miscellaneous compositions) makes the stars a little 'fuzzy', making the stars much more easy to ignite. Without the wood meal prime the stars are often blown blind.

Preparation:

Potassium Perchlorate.....	75
Cryolite.....	10
Shellac.....	15

Yellow star #8

Source: rec.pyrotechnics

Comments: These compositions are part of a matched set invented by Robert Veline. The compositions mix compatibly to produce a wide range of other colors. Examples are given below. The wood meal in the prime (see miscellaneous compositions) makes the stars a little 'fuzzy', making the stars much more easy to ignite. Without the wood meal prime the stars are often blown blind.

Preparation:

Potassium Perchlorate.....	70
Cryolite.....	10
PVC.....	10
Shellac.....	10

Veline's red star

Source: rec. pyrotechnics, post by Lloyd E. Sponenburgh <lloyds@fiscalinfo.com>. This set of compositions was invented by Robert Veline and is used in Kosankie's 'Chemistry of Fireworks (Chemistry of color) class'.

Comments: These compositions are part of a matched set invented by Robert Veline. The compositions mix compatibly to produce a wide range of other colors. Examples are given below. The wood meal in the prime (see miscellaneous compositions) makes the stars a little 'fuzzy', making the stars much more easy to ignite. Without the wood meal prime the stars are often blown blind.

Preparation: Summary of Robert Veline's own comments: "Potassium perchlorate is a fine powder. Parlon is Hercules brand or Superchlone brand from Ishihara co. ltd. Red gum is a fine powder. Copper(II)oxide may be substituted by copper carbonate without much change in performance. Calcium carbonate is 200 mesh, 'Whiting'. More pure forms slow the burn rate and degrade the color."

Potassium perchlorate.....	55
Strontium carbonate.....	15
Parlon.....	15
Red gum.....	9
Magnalium (50/50), 200 mesh.....	6
Dextrin.....	+4

Veline's orange star

Source: rec. pyrotechnics, post by Lloyd E. Sponenburgh <lloyds@fiscalinfo.com. This set of compositions was invented by Robert Veline and is used in Kosankie's 'Chemistry of Fireworks (Chemistry of color) class'.

Comments: These compositions are part of a matched set invented by Robert Veline. The compositions mix compatibly to produce a wide range of other colors. Examples are given below. The wood meal in the prime (see miscellaneous compositions) makes the stars a little 'fuzzy', making the stars much more easy to ignite. Without the wood meal prime the stars are often blown blind.

Preparation: Summary of Robert Veline's own comments: "Potassium perchlorate is a fine powder. Parlon is Hercules brand or Superchlone brand from Ishihara co. ltd. Red gum is a fine powder. Copper(II)oxide may be substituted by copper carbonate without much change in performance. Calcium carbonate is 200 mesh, 'Whiting'. More pure forms slow the burn rate and degrade the color."

Potassium perchlorate.....	55
Calcium carbonate.....	15
Parlon.....	15
Red gum.....	9
Magnalium (50/50), 200 mesh.....	6
Dextrin.....	+4

Veline's green star

Source: rec. pyrotechnics, post by Lloyd E. Sponenburgh <lloyds@fiscalinfo.com. This set of compositions was invented by Robert Veline and is used in Kosankie's 'Chemistry of Fireworks (Chemistry of color) class'.

Comments: These compositions are part of a matched set invented by Robert Veline. The compositions mix compatibly to produce a wide range of other colors. Examples are given below. The wood meal in the prime (see miscellaneous compositions) makes the stars a little 'fuzzy', making the stars much more easy to ignite. Without the wood meal prime the stars are often blown blind.

Preparation: Summary of Robert Veline's own comments: "Potassium perchlorate is a fine powder. Parlon is Hercules brand or Superchlone brand from Ishihara co. ltd. Red gum is a fine powder. Copper(II)oxide may be substituted by copper carbonate without much change in performance. Calcium carbonate is 200 mesh, 'Whiting'. More pure forms slow the burn rate and degrade the color."

Potassium perchlorate.....	30
Barium nitrate.....	24
Barium carbonate.....	15
Parlon.....	15
Red gum.....	5
Magnalium (50/50), 200 mesh.....	11
Dextrin.....	+4

Veline's blue star

Source: rec. pyrotechnics, post by Lloyd E. Sponenburgh <lloyds@fiscalinfo.com. This set of compositions was invented by Robert Veline and is used in Kosankie's 'Chemistry of Fireworks (Chemistry of color) class'.

Comments: These compositions are part of a matched set invented by Robert Veline. The compositions mix compatibly to produce a wide range of other colors. Examples are given below. The wood meal in the prime (see miscellaneous compositions) makes the stars a little 'fuzzy', making the stars much more easy to ignite. Without the wood meal prime the stars are often blown blind.

Preparation: Summary of Robert Veline's own comments: "Potassium perchlorate is a fine powder. Parlon is Hercules brand or Superchlone brand from Ishihara co. Ltd. Red gum is a fine powder. Copper(II)oxide may be substituted by copper carbonate without much change in performance. Calcium carbonate is 200 mesh, 'Whiting'. More pure forms slow the burn rate and degrade the color."

Potassium perchlorate.....	55
Copper(II)oxide.....	15
Parlon.....	15
Red gum.....	9
Magnalium (50/50), 200 mesh.....	6
Dextrin.....	+4

Veline's mixed colors

Source: rec. pyrotechnics, post by Lloyd E. Sponenburgh <lloyds@fiscalinfo.com.

Comments: These are a few examples of the colors that can be obtained by mixing a few of Robert Veline's set of star compositions.

Preparation:

Yellow.....	55 green, 45 orange
Chartreuse.....	80 green, 20 orange
Aqua.....	80 green, 20 blue
Turquoise.....	55 green, 45 blue
Magenta.....	50 red, 50 blue
Maroon.....	85 red, 15 blue
Peach.....	60 orange, 25 red, 15 blue
Purple.....	5 orange, 15 red, 80 blue

Chapter 9: effect stars

White flare star

Source: "Vuurwerk door de eeuwen heen"[11]

Comments: Dangerous mixture since it contains both sulfur and a chlorate.

Preparation: Wet with solution of shellac in ethanol. ±20g Shellac per liter of ethanol.

Potassium nitrate.....	165
Sulfur.....	31
Barium nitrate.....	455
Barium chlorate.....	31
Magnesium powder.....	18
Aluminum medium course.....	5
Aluminum fine.....	25

Gold flitter star

Source:

Comments: The particle sizes of aluminum powders will markedly affect the result. If Al bronze is available, you can use all 16 parts of it instead of the two different Al powders.

Preparation: Add water and proceed as usual.

Potassium nitrate, fine.....	16
------------------------------	----

Sulfur.....	3
Charcoal, powdered.....	2
Sodium oxalate or Ultramarine.....	4 or 2
Fine, grey aluminum powder (preferably pyro Aluminum).....	11
Flake Aluminum or medium Al powder (Al bronze works well).....	5
Dextrin.....	4

Zinc spreader star #1

Source: "The Pyroguide" (a document found on internet)

Comments: The stars spread pieces of burning zinc and charcoal. These stars are much heavier than usual, and require larger lifter charges if they're to be fired from a tube.

Preparation: Bind with water.

Zinc dust.....	72
Potassium chlorate.....	15
Potassium dichromate.....	12
Granular charcoal.....	12
Dextrin.....	2

Zinc spreader star #2

Source: "The Pyroguide" (a document found on internet)

Comments:

Preparation: Bind with dextrin in water.

Potassium nitrate.....	14
Zinc dust.....	40
Charcoal.....	7
Sulfur.....	4

Zinc spreader star #3

Source: "The Pyroguide" (a document found on internet)

Comments: Bind with dextrin in water.

Preparation:

Potassium chlorate.....	5
Potassium dichromate.....	4
Charcoal, medium.....	4
Zinc dust.....	24

Willow tree star

Source: "The Pyroguide" (a document found on internet)

Comments: Dangerous mixture since it contains both sulfur and a chlorate.

Preparation: Bind with dextrin in water.

Potassium chlorate.....	10
Potassium nitrate.....	5
Sulfur.....	1
Lampblack.....	18

Soft willow lampblack star

Source: "Mesquite charcoal" from Tom Perigrin's homepage.

Comments:

Preparation: Use a meal powder prime. 1 part shellac can be used instead of 5 parts, burning time will be reduced by 2 sec. Standard willow method: mix the components, wet with alcohol/water screen pulverone style, dry, mill for 3 hours then make cut stars. Adding extra charcoal might slow the burn, giving a better tail.

Charcoal.....	25
Dextrin.....	5
Potassium nitrate.....	10
Potassium perchlorate.....	30
Lampblack.....	30
Shellac.....	5

Lampblack willow star

Source: PML, post by Bill Ofca <ofca@csbh.mhv.net

Comments:

Preparation: Dampen with 50/50 water/alcohol as it is rolled over a (chlorate) core star or stars containing NO sulfur or sulfur compounds. It helps to slightly dampen the lampblack with pure alcohol before it is mixed with the other dry ingredients. Once thoroughly mixed, it should still flow as a powder, or too much alcohol was used. If that happens, allow it to evaporate for awhile until it can be sprinkled on the rolling stars.

Lampblack.....	12
Potassium chlorate.....	8
Potassium nitrate.....	1
Dextrin.....	1

Silver shower star #1

Source:

Comments:

Preparation: Add water and proceed as usual. The particle size and surface area of the reactants has a profound effect on the results.

Potassium nitrate.....	35
Fine charcoal.....	8
Boric acid.....	2
Sulfur.....	7
Potassium perchlorate.....	60
Fine pyro Aluminum (atomised Aluminum, 0.1 mm)....	20
Fine flake aluminum (Al bronze).....	25
Coarse flake Aluminum.....	15
Dextrin.....	10

Silver shower star #2

Source: PML, post by Charley Wilson <cwilson@celsvr.stortek.com.

Comments: The particle size of the aluminum is not very critical.

Preparation: Dissolve shellac in boiling ethanol, mix in the other ingredients and proceed as usual. Shellac stars take a long time to dry; try drying in the sun. Prime with a perchlorate based strobe prime.

Ammonium perchlorate.....	65
Fine aluminum powder or flake aluminum (not too coarse)....	22
Shellac.....	18

Silver shower star #3

Source:

Comments:

Preparation: Add water and proceed as usual.

Flitter Aluminum (or any grade except the finest pyro grades)....	15
Potassium nitrate.....	55
Boric acid.....	2

Fine charcoal.....	10
Dextrin.....	5

Electric star #1

Source: "The Pyroguide" (a document found on internet)

Comments:

Preparation: Bind with dextrin in water.

Potassium nitrate.....	15
Aluminum, fine.....	2
Aluminum, medium.....	1
Black powder.....	2
Antimony sulfide.....	3
Sulfur.....	4

Electric star #2

Source: "The Pyroguide" (a document found on internet)

Comments:

Preparation: Bind with red gum in water.

Potassium chlorate.....	60
Barium nitrate.....	5
Aluminum, fine.....	9
Aluminum, medium.....	4
Aluminum, coarse.....	3
Charcoal.....	2
Dextrin.....	5

Electric star #3

Source: "The Pyroguide" (a document found on internet)

Comments:

Preparation: Bind with shellac in alcohol.

Potassium perchlorate.....	6
Barium nitrate.....	1
Aluminum.....	20
Dextrin.....	1

Electric star #4

Source: "The Pyroguide" (a document found on internet)

Comments:

Preparation: Bind with shellac in alcohol.

Potassium perchlorate.....	4
Aluminum, medium.....	2
Dextrin.....	1

Firefly #1

Source: rec.pyrotechnics archive. Posted by Eric Eisack.

Comments:

Preparation: Aluminum is large flake. It was sieved through a window screen. This gives about 30 mesh powder.

Potassium nitrate.....	50
Charcoal, air float.....	29
Charcoal, 80 mesh.....	10.5

Sulfur.....	6
Aluminum (large flake).....	4.5
Dextrin or CMC.....	+5 or +1

Firefly #2

Source: rec.pyrotechnics archive. Posted by Dan Bucciano.

Comments: Can also be used as rocket propellant: Mix the chemicals, dampen, and granulate through a 20 mesh screen and dry. Use +3% by weight as a tail effect. Once you have passed the top core of the rocket by 1/2 inch, you may ram 100% firefly formula the rest of the way. You will end up with a beautiful long trailing tail of firefly.

Preparation:

Potassium Nitrate.....	47
Air Float Charcoal.....	33
Antimony tri-sulfide.....	5.8
Aluminum (400 mesh,12 micron, spherical).....	4.2
Sulfur.....	4.7
Dextrin.....	5.2

Firefly #3

Source: PML Digest 391, post by L.Nicksch <LNicksch@aol.com. This formula is provided with the "firefly aluminum" from Skylighter.

Comments:

Preparation: Ball mill potassium nitrate, Air Float charcoal, sulfur and Dextrin together for 1 hour. Then add the 36 mesh Charcoal and firefly aluminum and mix with a spoon. Add water to make a dough mix and cut with a knife into 3/8" cut stars. Separate stars and dry for 3-4 days. The effect is a long tiger tail going up and firefly sparkles coming down. Larger stars take longer to dry, and a damp star produces very little firefly effect.

Potassium nitrate.....	49
Charcoal, air float.....	29
Charcoal, 36 Mesh.....	11
Sulfur.....	9
Dextrin.....	10
Aluminum, firefly.....	5

Glitter star

Source: rec.pyrotechnics archive, post by Tommy Hakomaki <tommy.hakomaki@mailbox.swipnet.se

Comments:

Preparation: Wet with ethanol/water (70/30)

Potassium nitrate.....	55
Aluminum 200-400 mesh.....	5
Dextrin.....	4
Antimony(III)sulfide.....	16
Sulfur.....	10
Lampblack.....	10

Red Pill Box star

Source: rec.pyrotechnics archive. Composition from Lancaster[2]

Comments:

Preparation:

Potassium chlorate.....	64
Strontium carbonate.....	19
Red gum.....	13
Dextrin.....	4

Sparkler star

Source: rec.pyrotechnics archive.

Comments: Use coarse aluminum, fine aluminum will only result in a flash.

Preparation:

Potassium perchlorate.....60
Aluminum, coarse.....30
Dextrin.....10

White flitter star

Source: Tom's Perigrin's homepage. Composition from Weingart[5].

Comments:

Preparation:

Potassium nitrate.....17
Sulfur.....3
Charcoal.....3
Aluminum, coarse.....4
Aluminum flake, fine.....10
Dextrin.....1

White comet #1

Source: rec.pyrotechnics

Comments:

Preparation:

Potassium nitrate.....96
Fine charcoal.....44
Sulfur.....15
Dextrin.....10

White comet #2

Source: rec.pyrotechnics

Comments:

Preparation:

Potassium nitrate.....40
Fine charcoal.....24
Sulfur.....8
Dextrin.....9

'Dragon eggs' star (Crackling star)

Source: rec.pyrotechnics. Composition from "The best of AFN III"[12], page 121

Comments: Sometimes, Bi₂O₃ is used instead of Pb₃O₄. The composition is extremely sensitive, both to friction and impact. It is also quite poisonous and explosive. Gloves and an air mask must be worn at all times when handling this mixture since the mixture contains the very toxic Pb₃O₄.

Preparation: Add lacquer until the thickness is like wood putty. Pass the mix through a screen and dry it to make 1mm squares. These will explode with a sharp crack shortly after lighting and can be used as star cores.

Pb₃O₄.....81.8
Magnalium (50/50, 100-200 Mesh).....9.1
Copper(II)oxide.....9.1
Nitrocellulose lacquer binder.....10% by volume

Blue star with charcoal tail

Source: rec.pyrotechnics, posted by sweden <sweden@synchron.ct.se. Source of this composition is Bruce Snowden

Comments:

Preparation: Add isopropyl alcohol for binding. Cut, round and pumped stars can be made with this composition, but a typical KClO₄/Red gum/Charcoal/dextrin prime will be necessary. A final layer of sodium nitrate/sulfur/Charcoal (85/5/10), moistened with NC/acetone lacker (w. about 3% NC) can be added. This adds yellowish sparks. Mealpowder can be used instead if the yellow sparks are not desired.

Ammonium perchlorate.....70
Basic copper carbonate.....10
Red Gum.....10
Charcoal.....10
Dextrin.....+5

Electric purple star

Source: Quoted in an AFN Yearbook from David Bleser on "Protecting Electric Purple Decomposition"

Comments: When very fine powdered ammonium perchlorate was used in an attempt to try to increase the burning rate of stars an ammoniacal smell and an increase in temperature was noticed. The batch of stars was safely disposed of. By adding 5% potassium dichromate and 1% boric acid the reactions were prevented.

Preparation:

Ammonium perchlorate.....68
Copper benzoate.....8
Strontium carbonate.....12
Magnalium (200-400 Mesh).....5
Hexamine.....7
Dextrin.....+5

Brilliant core

Source: Composition from Shimizu[1], page 219.

Comments: This composition can be used for the cores of round stars. It gives a strong flash of light. The cores burn quickly and are self propelled when they are unevenly ignited. To prevent that, these cores should be coated with 'Brilliant core prime' (see miscellaneous compositions) until they are round.

Preparation:

Barium nitrate.....66
Aluminum, fine flake.....27
Boric acid.....1
Soluble glutinous rice starch.....6

Silver star core

Source: Composition from Shimizu[1], page 220.

Comments: This composition can be used for the cores of round stars. It burns less quickly than the 'brilliant core', and produces a silver flame.

Preparation:

Potassium perchlorate.....56
Rosin (BL combustion agent).....5
Aluminum (fine flake).....32
Lampblack.....2
Soluble glutinous rice starch.....5

Silver wave

Source: Composition from Shimizu[1], page 220.

Comments: This composition produces a silver fire dust. A large silver fire dust flame of short duration is obtained.

When the ratio perchlorate to aluminum is changed to 35/65 a small flame with yellowish fire dust of long duration is obtained.

Preparation:

Potassium perchlorate.....50
Aluminum (somewhat coarse flake).....50
Soluble glutinous rice starch.....+5%

Golden wave #1

Source: Composition from Shimizu[1], page 221

Comments:

Preparation:

Potassium nitrate.....37
Aluminum (somewhat coarse flake).....47
Antimony trisulfide.....9
Boric acid.....1
Soluble glutinous rice starch.....6

Golden wave #2

Source: Composition from Shimizu[1], page 221.

Comments:

Preparation:

Potassium nitrate.....37
Aluminum (somewhat coarse flake).....47
Sulfur.....9
Boric acid.....1
Soluble glutinous rice starch.....6

Golden wave #3

Source: Composition from Shimizu[1], page 221.

Comments: A somewhat reddish gold effect is obtained with this composition.

Preparation:

Potassium nitrate.....37
Aluminum (somewhat coarse flake).....47
Realgar.....9
Boric acid.....1
Soluble glutinous rice starch.....6

Golden chrysanthemum

Source: Composition from Shimizu[1], page 221.

Comments: This produces a brilliant yellow fire dust.

Preparation:

Potassium nitrate.....40
Aluminum (somewhat coarse flake).....30
Sulfur.....10
Realgar.....10
Hemp coal (or pauownia coal).....2
Boric acid.....1
Soluble glutinous rice starch.....7

Charcoal fire dust #1

Source: Composition from Shimizu[1], page 221. Listed under the name "Chrysanthemum 6". The 6 in that name comes from the ratio of charcoal to potassium nitrate, which is 6:10.

Comments: A reddish fire dust is obtained, which is relatively shortlived. When willow charcoal is used instead of pine, long lived fire dust is obtained.

Preparation: To obtain the fire dust, the potassium nitrate must be soaked into the charcoal. Hence a wet proces must be used for mixing.

Potassium nitrate.....55
Sulfur.....7
Pine charcoal.....33
Soluble glutinous rice starch.....5

Charcoal fire dust #2

Source: Composition from Shimizu[1], page 221. Listed under the name "Chrysanthemum 8". The 8 in that name comes from the ratio of charcoal to potassium nitrate, which is 8:10.

Comments: A reddish fire dust is obtained, which is relatively shortlived. When willow charcoal is used instead of pine, long lived fire dust is obtained.

Preparation: To obtain the fire dust, the potassium nitrate must be soaked into the charcoal. Hence a wet proces must be used for mixing.

Preparation: Potassium nitrate.....49
Sulfur.....6
Pine charcoal.....40
Soluble glutinous rice starch.....5

Charcoal fire dust #3

Source: Composition from Shimizu[1], page 221. Listed under the name "Chrysanthemum of mystery".

Comments: A weak fire dust is obtained since the composition contains no sulfur. It creates a different and lonely effect.

Preparation: To obtain the fire dust, the potassium nitrate must be soaked into the charcoal. Hence a wet proces must be used for mixing.

Potassium nitrate.....45
Pine charcoal.....50
Soluble glutinous rice starch.....5

Charcoal fire dust #4

Source: Composition from Shimizu[1], page 221. Listed under the name "Tiger tail".

Comments:

Preparation: To obtain the fire dust, the potassium nitrate must be soaked into the charcoal. Hence a wet proces must be used for mixing.

Potassium nitrate.....44
Sulfur.....6
Pine charcoal.....44
Soluble glutinous rice starch.....6

Charcoal fire dust #5

Source: Composition from Shimizu[1], page 221. Listed under the name "Willow".

Comments:

Preparation: To obtain the fire dust, the potassium nitrate must be soaked into the charcoal. Hence a wet proces must be used for mixing.

Potassium nitrate.....35
Sulfur.....12

Pine charcoal.....	45
Soluble glutinous rice starch.....	8

Silver wave chrysanthemum

Source: Composition from Shimizu[1], page 222.

Comments: A fire dust with sparks from the metal powder is obtained. It looks as if red, yellow and green twinkling fire particles were mixed together.

Preparation: The potassium nitrate, sulfur and pine charcoal are previously mixed densely as in the manufacture of black powder.

Potassium nitrate.....	50
Sulfur.....	17.5
Pine charcoal.....	7.5
Aluminum (somewhat coarse flake).....	7.5
Magnalium.....	1.5
Antimony trisulfide.....	2.5
Realgar.....	7.5
Soluble glutinous rice starch.....	6.0

Metal fire dust No.32

Source: Composition from Shimizu[1], page 221. Listed under the name "Winokur's compositions". They originated from "The pyrotechnic phenomenon of glitter" by R. M. Winokur from Pyrotechnica No 2, february 1978

Comments:

Preparation:

Potassium nitrate.....	38
Sulfur.....	13
Charcoal.....	10
Barium nitrate.....	14
Aluminum, Atomized.....	12
Red Iron Oxide, Fe ₂ O ₃	8
Dextrin.....	5

Metal fire dust No.33

Source: Composition from Shimizu[1], page 221. Listed under the name "Winokur's compositions". They originated from "The pyrotechnic phenomenon of glitter" by R. M. Winokur from Pyrotechnica No 2, february 1978

Comments:

Preparation:

Potassium nitrate.....	43
Sulfur.....	10
Charcoal.....	10
Barium nitrate.....	13
Aluminum, Atomized.....	13
Red Iron Oxide, Fe ₂ O ₃	7
Dextrin.....	4

Metal fire dust No.34

Source: Composition from Shimizu[1], page 221. Listed under the name "Winokur's compositions". They originated from "The pyrotechnic phenomenon of glitter" by R. M. Winokur from Pyrotechnica No 2, february 1978

Comments:

Preparation:

Potassium nitrate.....	40
Sulfur.....	10

Charcoal.....	10
Barium nitrate.....	16
Aluminum, Atomized.....	12
Red Iron Oxide, Fe ₂ O ₃	7
Dextrin.....	5

Metal fire dust No.35

Source: Composition from Shimizu[1], page 221. Listed under the name "Winokur's compositions". They originated from "The pyrotechnic phenomenon of glitter" by R. M. Winokur from Pyrotechnica No 2, february 1978

Comments:

Preparation:

Potassium nitrate.....	36
Sulfur.....	13
Charcoal.....	10
Barium nitrate.....	16
Aluminum, Atomized.....	12
Red Iron Oxide, Fe ₂ O ₃	8
Dextrin.....	5

Metal fire dust No.38

Source: Composition from Shimizu[1], page 221. Listed under the name "Winokur's compositions". They originated from "The pyrotechnic phenomenon of glitter" by R. M. Winokur from Pyrotechnica No 2, february 1978

Comments:

Preparation:

Potassium nitrate.....	40
Sulfur.....	12
Charcoal.....	12
Barium nitrate.....	13
Aluminum, Atomized.....	12
Red Iron Oxide, Fe ₂ O ₃	7
Dextrin.....	4

Matrix comet composition #1

Source: PML 8 oct 96, post by Myke Stanbridge <mykestan@cleo.murdoch.edu.au

Comments: A matrix comet consists of a matrix composition in which colored microstars are embedded. It produces a colored tail when fired. The microstars must be slow-burning while the matrix must be very fast burning. The matrix must either emit as little light as possible or a lot of light in a color that is compatible with the color of the microstars. The following green matrix composition from c1995 is a good starting point for further experimentation.

Preparation: Exfoliated mica is also called Vermiculite. It is usually obtained from 'mineral products' suppliers in graded sizes from around 5 to 10 millimetres. It requires comminution in a coffee mill, followed by screening. The guar binder, although very effective in low amounts, has a very slow drying profile and a tendency to produce a 'skin' that prevents 'radiant heat source' drying. To dry the comets uniformly requires a fan circulated 'dry air' drier. Large 3" comets might take two months to dry properly depending on the circumstances.

Potassium chlorate, passing 200 mesh.....	50
Barium benzoate, passing 100 mesh.....	23
Barium carbonate, passing 200 mesh.....	10
Exfoliated mica, pass 80 mesh, hold 120 mesh.....	10
Bentonite clay - wyoming, passing 200 mesh.....	6
Guar gum fine WW250F, passing 200 mesh.....	1

Matrix comet composition #2

Source: PML 8 oct 96, post by Myke Stanbridge <mykestan@cleo.murdoch.edu.au

Comments: A matrix comet consists of a matrix composition in which colored microstars are embedded. It produces a colored tail when fired. The microstars must be slow-burning while the matrix must be very fast burning. The matrix must either emit as little light as possible or a lot of light in a color that is compatible with the color of the microstars. The following green matrix composition from c1995 is a good starting point for further experimentation.

Preparation: Exfoliated mica is also called Vermiculite. It is usually obtained from 'mineral products' suppliers in graded sizes from around 5 to 10 millimetres. It requires comminution in a coffee mill, followed by screening. The guar binder, although very effective in low amounts, has a very slow drying profile and a tendency to produce a 'skin' that prevents 'radiant heat source' drying. To dry the comets uniformly requires a fan circulated 'dry air' drier. Large 3" comets might take two months to dry properly depending on the circumstances.

Potassium perchlorate, passing 100 mesh.....50
 Zirconium silicate, passing 325 mesh.....30
 Polykarbenite-3 - Armex, passing 200 mesh.....10
 Barium carbonate, passing 200 mesh.....9
 Guar gum fine WW250F, passing 200 mesh.....1

Chapter 10: strobe stars

Twinkling green star #1

Source: rec.pyrotechnics, posted by Bill Nelson <billn@peak.org, from "Pyrotechnica VII"[3] by T. Fish

Comments: Magnesium reacts slowly with ammonium perchlorate producing ammonia and magnesium perchlorate, especially in the presence of moisture. Thus, the twinklers cannot be stored for more than 6 months, and they must be kept in a closed bag. During the smoulder phase, magnesium reacts with ammonium perchlorate in the dark. In the flash phase, magnesium reacts with barium sulfate, producing hot MgO and creating a green flame. The flash is followed by another cycle, since the flash rapidly consumes the reactants in the flash zone.

Preparation: 1) Binder solution: Dissolve 3 parts of nitrocellulose (smokeless powder or celluloid film) into 30 parts (w/v) of boiling acetone. If you're going to prepare these stars more than once, prepare more of the solution, since nitrocellulose dissolves slowly even in refluxing acetone. Approx. 30 parts of the solution (v/w) is used each time. Nitrocellulose is used as a binder, since other binders tend to interfere with the twinkling. 2) Mix the ingredients into the binder solution in the order they appear here. Proceed as usual. Note that acetone evaporates very rapidly and the stars usually dry within a few hours.

Magnesium powder (any lab grade powder).....23
 Ammonium perchlorate.....60
 Barium sulfate.....17

Twinkling green star #2

Source: Composition from Shimizu[1], page 224. Listed as "Twinklers of the ammonium perchlorate base, green"

Comments: Frequency: 3.1 Hz.

Preparation: Add 25 parts 10% nitrocellulose solution in acetone to 100 parts of the composition, and make cut stars. Roll these stars in "priming composition #8", using the same NC paste until stars are round. Add a final layer of black powder in NC paste to ensure ignition.

Magnesium, 60 mesh (treated with potassium bichromate).....23
 Ammonium perchlorate.....60
 Barium sulfate.....17
 Potassium dichromate (as a stabilizer).....+5%

Twinkling green star #3

Source: Composition from Shimizu[1], page 225. Listed as "Twinklers of the nitrate base, green"

Comments:

Preparation: Add 25 parts 10% nitrocellulose solution in acetone to 100 parts of the composition, and make cut stars.

Roll these stars in "priming composition #8", using the same NC paste until stars are round. Add a final layer of black powder in NC paste to ensure ignition.

Magnalium.....18 (coated with linseed oil) Barium nitrate[40
BHC (Benzene hexachloride).....5
Sulfur.....30
Antimony trisulfide.....7
•Twinkling red star Class:10.....50

Twinkling red star

Source: PML 383, composition comes from a post to rec.pyrotechnics by Myke Stanbridge <mykestan@cleo.murdoch.edu.au in '95

Comments:

Preparation: Magnesium was treated with cold 10% w/w K₂Cr₂O₇ in deionised water for 2 hours.

Ammonium perchlorate, 100 mesh.....50
Magnesium metal, 120 mesh.....23
Strontium sulfate, 100 mesh.....18
Genchlor GC 700-200, 160 mesh.....2
Winchester DB-231 as grain pwd.....7
Acetone, water free technical.....+20% (w/w)

Twinkling white star #1

Source: PML, posted by Harry Galliam <HEGilliam@aol.com. Composition from Bleser[13], page 22. Listed as "formulation #26; white strobe".

Comments:

Preparation: The magnalium needs to be treated with potassium dichromate before mixing.

Barium nitrate.....51
Sulfur.....19
Magnalium, 100 Mesh.....18
Potassium nitrate.....7
Dextrin.....5

Twinkling white star #2

Source: Composition from Shimizu[1], page 224. Listed as "Twinklers of the ammonium perchlorate base, white"

Comments: Frequenty: 9.7 Hz.

Preparation: Add 25 parts 10% nitrocellulose solution in acetone to 100 parts of the composition, and make cut stars. Roll these stars in "priming composition #8", using the same NC paste until stars are round. Add a final layer of black powder in NC paste to ensure ignition.

Magnalium, 80 mesh (treated with potassium bichromate).....25
Ammonium perchlorate.....60
Barium sulfate.....15
Potassium dichromate (as a stabilizer).....+5%

Twinkling red star

Source: Composition from Shimizu[1], page 224. Listed as "Twinklers of the ammonium perchlorate base, red"

Comments: Frequenty: 3.5 Hz.

Preparation: Add 25 parts 10% nitrocellulose solution in acetone to 100 parts of the composition, and make cut stars. Roll these stars in "priming composition #8", using the same NC paste until stars are round. Add a final layer of black powder in NC paste to ensure ignition.

Magnesium, 60 mesh (treated with potassium bichromate).....30
Ammonium perchlorate.....50

Strontium sulfate.....20
Potassium dichromate (as a stabilizer).....+5%

Twinkling orange star

Source: Composition from Shimizu[1], page 224. Listed as "Twinklers of the ammonium perchlorate base, orange"

Comments: Frequent: 6.9 Hz.

Preparation: Add 25 parts 10% nitrocellulose solution in acetone to 100 parts of the composition, and make cut stars. Roll these stars in "priming composition #8", using the same NC paste until stars are round. Add a final layer of black powder in NC paste to ensure ignition.

Magnesium, 60 mesh (treated with potassium bichromate).....30
Ammonium perchlorate.....60
Calcium sulfate.....10
Potassium dichromate (as a stabilizer).....+5%

Twinkling yellow star #1

Source: Composition from Shimizu[1], page 224. Listed as "Twinklers of the ammonium perchlorate base, yellow"

Comments: Frequent: 3.5 Hz.

Preparation: Add 25 parts 10% nitrocellulose solution in acetone to 100 parts of the composition, and make cut stars. Roll these stars in "priming composition #8", using the same NC paste until stars are round. Add a final layer of black powder in NC paste to ensure ignition.

Magnesium, 60 mesh (treated with potassium bichromate).....40
Ammonium perchlorate.....50
Sodium sulfate.....10
Potassium dichromate (as a stabilizer).....+5%

Twinkling yellow star #2

Source: Composition from Shimizu[1], page 225. Listed as "Twinklers of the nitrate base, yellow"

Comments:

Preparation: Add 25 parts 10% nitrocellulose solution in acetone to 100 parts of the composition, and make cut stars. Roll these stars in "priming composition #8", using the same NC paste until stars are round. Add a final layer of black powder in NC paste to ensure ignition.

Magnesium (coated with linseed oil).....12
Barium nitrate.....33
Potassium nitrate.....7
BHC (Benzene hexachloride).....11
Sulfur.....27
Antimony trisulfide.....5
Sodium oxalate.....5

Twinkling blue star

Source: Composition in handwriting in the copy of Shimizu[1], present in the library of the Technical University of Delft.

Comments:

Preparation: Add 25 parts 10% nitrocellulose solution in acetone to 100 parts of the composition, and make cut stars. Roll these stars in "priming composition #8", using the same NC paste until stars are round. Add a final layer of black powder in NC paste to ensure ignition.

Magnesium, 60 mesh (treated with potassium bichromate).....23
Ammonium perchlorate.....60
Copper sulfate.....17
Potassium dichromate (as a stabilizer).....+5%

Golden twinkler star

Source: "The Pyroguide" (a document found on internet)

Comments: Bind with water. The stars fall through the air and burn in an "on and off" manner. The effect is spectacular.

Preparation: The stars must be pumped or cut.

Potassium nitrate.....	18
Sulfur.....	3
Lampblack.....	3
Aluminum.....	3
Antimony sulfide.....	3
Sodium oxalate.....	4

Chapter 11: smoke stars

Red smoke star

Source: Shimizu[1], page 226. Listed as "Smoke dye compositions for stars, red"

Comments:

Preparation: Wheat flour can be substituted for milk sugar. Produce as 10mm cut stars, and prime with meal powder.

Potassium chlorate.....	28
Milk sugar.....	20
Rhodamine B conc.....	30
Oil orange.....	22
Soluble glutinous rice starch.....	+3%

Yellow smoke star #1

Source: Composition from Shimizu[1], page 229. Listed as "Yellow dragon"

Comments: The smoke is more dense than that of dye smoke, but it looks dark yellow against the light of the sun. The smoke is poisonous.

Preparation: Make pressed stars.

Potassium nitrate.....	25
Sulfur.....	16
Realgar.....	59

Yellow smoke star #2

Source: Composition from Shimizu[1], page 228. Listed as "White willow"

Comments:

Preparation:

Potassium nitrate.....	48.5
Sulfur.....	48.5
Realgar.....	3
Charcoal (or hemp coal).....	+2%
Soluble glutinous rice starch.....	+6%

Yellow smoke star #3

Source: Composition from Shimizu[1], page 229. Listed as "Yellow willow"

Comments:

Preparation: Form into cut stars, and dry them well. Place them in a coating tub. Add a slurry of soluble glutinous rice starch and cover all the surfaces with the paste by shaking the tub. Remove from the tub and place them on gypsum powder. Roll them in it until all the stars are coated with the gypsum. Dry in the sun. Repeat these operations until the

layer of gypsum becomes thicker than 1.5mm. It will be necessary to repeat at least 6 times. When done, bore a hole in each star to introduce the fire in it (with appropriate precautions taken). Prime the hole with black powder paste and dry in the sun. Roll a final layer of soluble glutinous rice starch and meal powder over the stars and dry them thoroughly.

Potassium nitrate.....	43
Sulfur.....	10
Realgar.....	37
Hemp coal (or Paulownia coal).....	4
Soluble glutinous rice starch.....	6

Green smoke star

Source: Composition from Shimizu[1], page 226. Listed as "Smoke dye compositions for stars, green"

Comments:

Preparation: Wheat flour can be substituted for milk sugar. Produce as 10mm cut stars, and prime with meal powder.

Potassium chlorate.....	33
Milk sugar.....	27
Oil yellow (Butter yellow).....	20
Phthalocyanine blue.....	20
Soluble glutinous rice starch.....	+3%

Blue smoke star

Source: Composition from Shimizu[1], page 226. Listed as "Smoke dye compositions for stars, blue"

Comments:

Preparation: Wheat flour can be substituted for milk sugar. Produce as 10mm cut stars, and prime with meal powder.

Potassium chlorate.....	33
Milk sugar.....	27
Phthalocyanine blue.....	40
Soluble glutinous rice starch.....	+3%

Violet smoke star

Source: Composition from Shimizu[1], page 226. Listed as "Smoke dye compositions for stars, Violet"

Comments:

Preparation: Wheat flour can be substituted for milk sugar. Produce as 10mm cut stars, and prime with meal powder.

Potassium chlorate.....	29
Milk sugar.....	25
Rhodamine B conc.....	13
Oil orange.....	16
Phthalocyanine blue.....	17
Soluble glutinous rice starch.....	+3%

White smoke star #1

Source: Composition from Shimizu[1], page 228. Listed as "White chrysanthemum I"

Comments:

Preparation:

Potassium nitrate.....	53
Sulfur.....	7
Charcoal (or hemp coal).....	32
Lampblack.....	8
Soluble glutinous rice starch.....	+6%

White smoke star #2

Source: Composition from Shimizu[1], page 228. Listed as "White chrysanthemum II"

Comments:

Preparation:

Potassium nitrate.....	66
Realgar.....	13
Charcoal (or hemp coal).....	5
Lampblack.....	5
Soluble glutinous rice starch.....	11

White smoke star #3

Source: Composition from Shimizu[1], page 228. Listed as "White willow"

Comments: The smoke is caused by condensation of sulfur vapour.

Preparation: Form into cut stars, and dry them well. Place them in a coating tub. Add a slurry of soluble glutinous rice starch and cover all the surfaces with the paste by shaking the tub. Remove from the tub and place them on gypsum powder. Roll them in it until all the stars are coated with the gypsum. Dry in the sun. Repeat these operations until the layer of gypsum becomes thicker than 1.5mm. It will be necessary to repeat 6 times. When done, bore a hole in each star to introduce the fire in it (with appropriate precautions taken). Prime the hole with black powder paste and dry in the sun. Roll a final layer of soluble glutinous rice starch and meal powder over the stars and dry them thoroughly.

Potassium nitrate.....	48.5
Sulfur.....	48.5
Realgar.....	3
Charcoal (or hemp coal).....	+2%
Soluble glutinous rice starch.....	+6%

Literature references

In some cases the original source of the composition is known. In those cases a short reference has been made, and the full references are given here.

1. T. Shimizu, "Fireworks: The Art, Science and Technique", Pyrotechnica Publications, Austin, Texas, USA (1981)
2. R. Lancaster, "Fireworks, Principles and Practice", Chemical Publishing Co., Inc. New York (1972)
3. "Pyrotechnica", Pyrotechnica publications, Austin, Texas, I(1977)-VI(1980)
4. H. Ellern, "Modern Pyrotechnics", Chemical Publishing Co., Inc. New York (1961)
5. G.W. Weingart, "Pyrotechnics", Chemical Publishing Co., Inc. New York (1947)
6. L.P. Edel, "Mengen en Roeren", 2nd edition (1936)
7. E. L. Palder, "Magic With Chemistry" (1964)
8. Kirk-Othmer "Encyclopedia of Chemical Technology"
9. D. Douwes, "Spelen met Vuur"
10. T.L. Davis, "Chemistry of Powder and Explosives", Wiley, London (1941)
11. J. Lenselink, "Vuurwerk door de eeuwen heen"
12. "The best of AFN III"

13. D. Bleser, "Round Stars and Shells"

14. "The best of AFN II"

Making black powder

The practice of making black powder (often abbreviated 'BP') is often oversimplified in textbooks. Merely mixing the components, potassium nitrate, charcoal and sulfur, does not result in real black powder. The mixture thus obtained is called 'green powder' or 'polverone'. It burns relatively slowly and leaves a lot of solid, unburned, material (residue). 'Real' black powder burns far more rapidly, leaving almost no residue. Its properties are very different from polverone. Making black powder at home takes some effort. It will require the use of a piece of equipment called a [ball mill](#) and can be produced by two methods. Either of the two methods described below is of suitable quality for most common purposes. The powder could be further improved by pressing and corning, if required, but this will not be described on this page.

The components

The standard formulation for black powder is: 75 parts potassium nitrate, 15 parts charcoal and 10 parts sulfur (as always, all parts are by weight).

You can find information on acquiring these chemicals in the [chemicals](#) section

Which method to use

There are two methods to make BP: The ball mill method and the precipitation (or 'CIA') method. You'll need a [ball mill](#) in any case. While both methods work, they each have their own advantages and disadvantages. The main disadvantage of the ball mill method is that it is essential that you have a safe place to let your mill do its work. You need a place with no buildings, people or animals whatsoever in the neighbourhood, and you need to be able to turn it on and off remotely. It also makes a lot of noise. Advantage of the ball mill method is that it is less laborious. You can simply charge your mill with the ingredients, turn it on, do something else for a couple of hours and you're done. The CIA method is much more work: you first mill the charcoal and sulfur together (just like you would with the ball mill method), but this is followed by dissolving the potassium nitrate in hot boiling water which is then mixed with the milled charcoal/sulfur mixture. The potassium nitrate is then precipitated from the solution by mixing with ice cold isopropyl alcohol. This is followed by filtering (messy) and drying (takes a long time, and a good place with no ignition sources, since there is a flammable liquid involved).

The ball mill method

1. Take your raw charcoal and crush it with a hammer between two sheets of paper. Wear old clothing and do this outside, since it is very messy. Sieve the charcoal through a coarse sieve (about 30 mesh).
2. Weigh the charcoal. To every 100 grams of charcoal, add 67 grams of sulfur, and fill 1/4th of your ball mill with this mixture. Put the media in and let the mill run for 3 hours.
3. When you open your mill, you should find an incredibly fine black/greyish powder. Sieve this to get the media of the mill out, and weigh it. In a separate container, place 75 grams of potassium nitrate for every 25 grams of charcoal/sulfur powder you have. Put the potassium nitrate in your ball mill, and mill it for 3 hours. You should have a very fine white/greyish powder.
4. Now mix the charcoal/sulfur mix with the potassium nitrate. Don't bother to mix it very thoroughly, since that will happen in the mill soon enough. To this mixture, add 6% of water. I spray it over the powder that I spread out on a sheet of paper to make sure all of it becomes wet. Put the wet powder in your mill and let it run for 5 hours. Every hour or so, check to see if the powder is still wet. If it dries out the risk of accidental ignition greatly increases.

5. Sieve the powder to get the media out, spread it out on a large sheet of paper and let it dry. If possible in the sun. Needless to say you shouldn't heat it in order to dry it more quickly, just be patient.

6. When dry, sieve the black powder through a few sieves to get several fractions for different purposes.

The precipitation method

1. Take your raw charcoal and crush it with a hammer between two sheets of paper. Wear old clothing and do this outside, since it is very messy. Sieve the charcoal through a coarse sieve (about 30 mesh).

2. Weigh the charcoal. To every 100 grams of charcoal, add 67 grams of sulfur, and fill 1/4th of your ball mill with this mixture. Put the media in and let the mill run for 8 hours.

3. While the mill is running, place 600 ml isopropylalcohol in a large container for every 100 grams of charcoal/sulfur mix you have, and place it in the fridge.

4. When you open your mill, you should find an incredibly fine black/greyish powder. Sieve this to get the media of the mill out, and weigh it. In a separate container, place 75 grams of potassium nitrate for every 25 grams of charcoal/sulfur powder you have. Put the potassium nitrate in an old pan, and add 40 ml tap water for every 100 grams of potassium nitrate.

5. Place the pan on the stove and bring it to a boil while continuously stirring. When the solution starts boiling, start adding small amounts of water while stirring all the time until all the potassium nitrate has dissolved.

6. Add an extra 10 ml tap water and the charcoal/sulfur mixture to the boiling potassium nitrate solution. Stir the charcoal/sulfur mixture in the solution. Make sure there are no dry clumps left.

7. By now, your isopropylalcohol should have cooled to at least 0 deg C or colder. Take the isopropylalcohol outside, and pour the potassium nitrate solution/charcoal/sulfur into the cold isopropylalcohol. Make sure there are no sources of ignition nearby! Stir for a few seconds.

8. Cool the mixture again to 0 deg C at the fastest rate you can. The faster the better.

9. Filter the mixture through an old cloth, and squeeze to get all the liquid out. Discard the black liquid.

10. Spread the black mush out on a sheet of paper, and dry it in the sun. Don't try to dry it inside since it will produce a lot of flammable vapour from the isopropylalcohol. When it is still slightly wet to the touch, press it through a sieve to corn it. Then dry it further.

11. When dry, sieve the black powder through a few sieves to get several fractions for different purposes.

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Black powder quality testing

The way black powder is made is of great influence on its quality. Several methods exist to determine the quality of black powder, but not all methods are quick and easily done at home. Also, it is not always clear what is considered 'good quality'. Different uses require different properties. With the method described below the burn rate of pressed black powder is determined. Keep in mind that the burn rate of pressed and loose (corned) black powder are usually different. Still, the test gives an objective indication of the burn rate which can be a measure of quality. For many purposes (lift charge, propellant) a high burn rate is good.

The test

1. Roll paper tubes of 12 mm inner diameter from 30*5 cm strips of paper. The kind of paper used probably influences the results so once you chose your paper use the same kind from then on. Fine tubes can be rolled from the brown gummed paper tape that is sold in artist paint supply stores. Use strips of about 30 cm length, 5 cm width (note the dimensions in your pyro journal and use the same sizes from then on). Let the tubes dry and fold a piece of tissuepaper (same paper every time, same size, folded the same way) and ram this in the tubes (same number of strokes, same pressure etc.).
2. Fill the tubes with black powder by scooping a small amount (same amount every time) in and ramming it with a wooden dowel and rubber hammer (same everything). Repeat this until the tubes are almost completely filled. Leave about 4 mm unfilled. Fill at least two tubes per type of black powder. Fold a piece of visco and place it on the black powder. Hold in place with a piece of tape on the outside of the tube.
3. Ignite the fuse and measure the burning time. Ofcourse this can be done with a stop watch, but it is more accurate to do this electronically. A convenient way is recording the sound of a burning tube. A burning tubes makes a reasonably loud rushing sound which can be easily recognized from background noise. If you then digitize the sound the burntime can be determined accurately with one of the many available (shareware)programs for sound manipulation. Another possibility is video taping the burning tube and counting the number of frames in slow motion playback.
4. Average the measurements.

Some results

Four types of black powder I stil had from previous experiments were tested. These powder are not representative for good black powder, but it illustrates the kind of results that can be obtained. The black powders were prepared as follows:

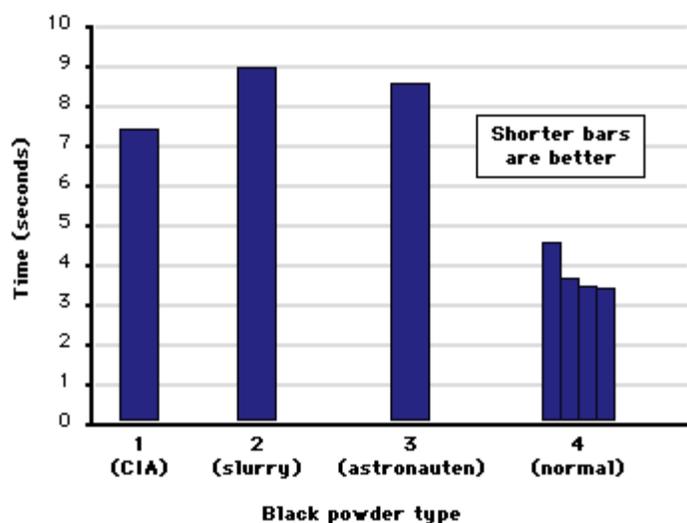
1. Willow charcoal with sulfur (=95% sulfur, 5% CaCO₃) mixed in a ball mill for 15 minutes. Proceeded with [precipitation \(CIA\) method](#) where denaturated ethanol was substituted for isopropyl alcohol. The short milling time makes this powder much slower than it could be.
2. Barbeque charcoal (brand 'Pyrogrill') was crushed with a hammer and sieved through a (coarse) sieve for kitchen use. The charcoal was mixed with 'spuitzwavel' (=80% sulfur) and potassium nitrate. To this mixture more than enough boiling hot water was added to dissolve the pottassium nitrate. This was heated until it was boiling again and slow heating with contineous vigorous stirring was continued until a slurry formed. The slurry was cooled as quickly as possible in an icebath. Upon cooling the mass solidified. The chunks that formed were dried in the sun, crushed and sieved. **WARNING:** this is not a safe way to prepare black powder and it should never be used.
3. A few firecrackers ('astronauten' from Schuurmans, Leeuwarden). were opened and the black powder was taken out.
- 4 (I tm IV). Willow charcoal was mixed with gardening sulfur (=95% sulfur, 5% CaCO₃) and the mixture was ball

milled for 3 hours. The potassium nitrate was ball milled separately for 1 hour. The potassium nitrate and charcoal/sulfur mixture were mixed and wetted with 6% (by weight) of a denatured alcohol/water mixture (50:50). The wet mix was ball milled for another hour. Four batches of this type of black powder were made and tested: 4I, 4II, 4III and 4IV. This is the [ball mill method](#).

The following average burn times and standard deviations were measured:

Black powder	average burn time (s)	abs. standard deviation (s)
1.. 'CIA'	7.39	0.05
2.. 'slurry'	8.97	0.03
3.. 'astronauten'	8.54	0.08
4I... 'normal'	4.55	0.15
4II... 'normal'	3.66	0.04
4III... 'normal'	3.430	0.024
4IV... 'normal'	3.40	0.03

Set out in a graph:



It is seen that the powder made by the ball milling method is by far the quickest of the types tested. Also, the powder Schuurmans puts in their crackers (nr. 3) is relatively slow. This powder has a dark color (compared to the other powders) and may have a higher carbon content than the standard formulation 75/15/10 (KNO₃/charcoal/S). The method is accurate enough to distinguish between batches of black powder. All four batches were made with the same method using the same ingredients. A new batch of charcoal was prepared for each individual batch of black powder though, which may explain the differences between the batches.

It would be interesting to use this test to see what the effect of different charcoals is on the burn rate. Also, the effect of additions of small amounts of some other compounds may be interesting.

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Ball Mill

A ball mill is device that can be used to grind chemicals much more easily and to a finer consistency than can possibly be done by hand with a mortar and pestle. It is often usefull to grind chemicals in order to increase their surface area. This will generally increase the rate at which they react in a pyrotechnic composition and make mixtures more homogenous which results in a steady burn rate. For making good quality black powder at home a ball mill is essential, and black powder is needed in very many pyrotechnic devices.

Note: ball milling inevitably causes friction and shocks and possibly leads to static electricity buildup as well depending on the design. Ball milling of mixtures should only be attempted when an appropriate place is available to operate the mill (ie one where it causes no damage or injury in case of explosion) and it must be turned on and off remotely. Most chemicals can be milled more safely but several sets of balls and containers must be available to prevent contamination and milling of metal powders can be dangerous as they may become pyrophoric.

Materials

I used whatever I could get cheaply to construct my mill, so you will probably not be able to get the exact same materials and have to improvice somewhat.

Motor: I used to use a electrically powered drill to drive my mill, but several people have advised against it as these are not designed to operate for extended periods of time. They tend to get excessively hot and eventually fail. Old motors can be found in many places for little or no money. Washing machines for example contain durable motors and are often plentiful at scrap yards. Mine came from a pump from an old coffee machine.

Container: A piece of PVC sewer tubing works well. I use a 34 cm long 11 cm diameter piece, with two fitting end caps. PVC is hard and will not suffer from erosion as much as most other materials I've tried. This container has lasted about 150 hours of operation thus far and shows no visible signs of wear. One point of discussion is that PVC may accumulate significant amounts of static electricity during operation. I've tested if the container is able to attract small chips of polyethylene right after use, which it doesn't. I'm not entirely convinced PVC is harmless though. For some more ideas on this matter, check out [this page](#) on the charging of powders in a rotating drum. Strips of rubber from a bicycle tire are glued around the casing with hot melt glue to improve its grip on the roller.

Roller: The roller is conveniently made of PVC tubing as well. I used 2.5 cm outer diameter sewer tubing, but the diameter may be chosen depending on the speed of the motor availalable. The ratio of 2.5 cm (roller) to 11 cm (container) yields a factor 4.4. reduction in speed. As the motor operates at about 250 rpm, the container would theoratically rotate at a rate of about 60 rpm. In practice it reaches 50 rpm due to slipping. Somewhat faster would be more efficient. It used to operate at 80 rpm when I was still using the drill, and black powder would be ready in 3 hours. Now, it takes 5 hours to obtain a similar quality, but the time gain is not worth an expensive tool. The roller is coated with rubber to improve grip on the container. I did this by sliding the ends of cut inner tube from a bike tire on the ends of a piece of 2.5 cm PVC tubing. Inflating the tube allows it to slide over the PVC as the air escapes.

Media: Most of the money was spend on media. I bought 150 lead balls of 1.78 cm diameter in a hunting supplies store. They are used for reloading rifles. Lead and brass media are preferred as they don't spark. Sparks could accidentally ignite the mixture you are milling, with disastreous results. Other media such as glass, steel or ceramic can be used for pure chemicals and non explosive mixtures but not for ignitable substances. How much media will you need? I recall that it is most efficient to fill exactly half of your container with balls. My container is 11 cm diameter and 34 cm length, which took 150 lead balls of 1.78 cm diameter.

Assembling

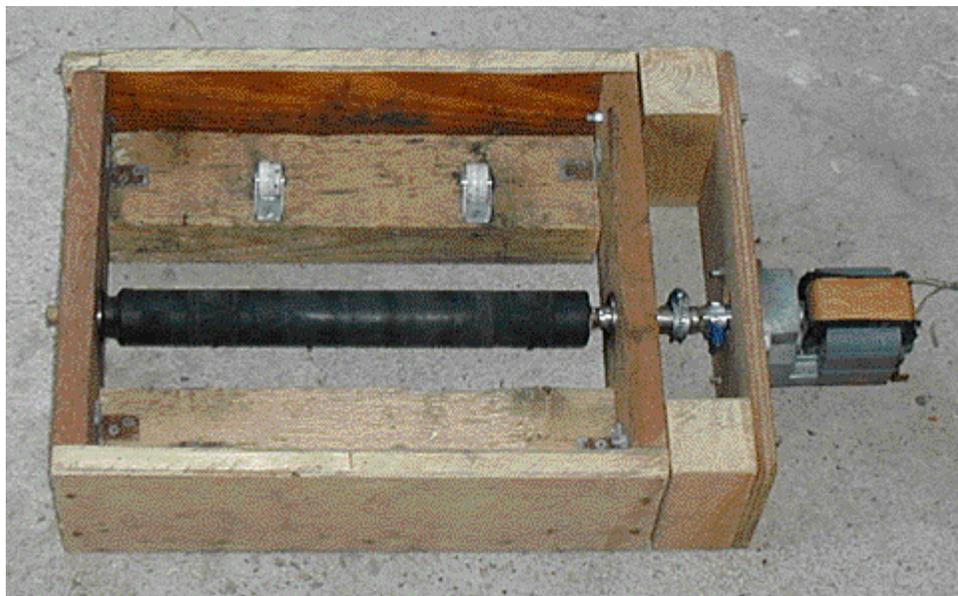
Constructing the mill is fairly simple. The [pictures](#) below illustrate the principle. The container rests on the roller and two small wheels. A copper rod lengthwise through the roller is driven by the motor on the right.

Using the mill

Ball milling can be dangerous. It inevitably causes friction and shocks that could ignite a mixture. Depending on your container and media material and the substance you are milling the process can generate static electricity as well. Milling metals can make them pyroforic. When a mixture ignites inside the mill the results can obviously be disastrous. The explosion will produce large amounts of shrapnell from the media and the milling container that can be hurled away hundreds of meters. Under no circumstances should you attempt to mill explosive mixtures such as black powder inside or near a building. Operate it on a piece of open terrain and turn the ball mill on and off remotely. Barricade it with sand bags. You can often safely mill pure compounds, but be aware that metals (which can be milled with steel media) can become pyroforic and ignite when you open the milling container (thereby letting oxygen in). Pyroforic metal powders can be very treacherous. They do not necessarily ignite immediately (although it could happen), but after some time when you think they are safe since there has been no reaction upon contact with air. When ignition occurs expect a large, extremely hot ball of flame, the burns of which can easily cause a painful death. Use your common sense when ball milling and be prepared for the worst.

I do not know wheter the materials I chose for my ball mill (PVC and lead) generate static electricity. I have prepared many batches of black powder in my mill (using a wet process) and have not had any accidents so far. Any comments on the above design are very welcome (wfvisser@dds.nl).

Pictures



This shows the basic construction. The black horizontal bar is the rubber-covered roller, driven by the motor on the right. The two small white structures are small plastic wheels, such as are used under furniture.

The container consists of a section of PVC tubing with fitting end caps. The picture shows some of the lead media (1.78 cm diameter lead balls), and a few chunks of charcoal. These will be broken up in the mill in a matter of minutes. Strips of rubber are glued around the container as shown to improve its grip on the roller.



The container where it belongs.

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