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REC.PYROTECHNICS FAQ
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1. Introduction - Welcome to rec.pyrotechnics

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Rec.pyrotechnics is a worldwide newsgroup dedicated to the discussion of fireworks and explosives, mostly concerned with their construction. The readers of rec.pyrotechnics welcome anyone with an interest in the subject, be they experienced or just trying to get started in the hobby.

If you are just getting started, try to get hold of as much information on the subject as you can, and read it carefully. If it is explosives you are interested in, make sure you read up on the theory behind explosives. There is a lot of misinformation in movies etc. regarding explosives, so it is important you get a good background from a reliable source.

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In the Pyrotechnic Literature section below are several books that are must-reads for anyone serious about pyrotechnics. Try all your local libraries - even if they don't have the books mentioned below, they are sure to have some information on the subject. Remember, you can never be too well-informed - it is **your** safety that is at stake, and not being aware of all the aspects involved is extremely dangerous.

Pyrotechnics and explosives are not safe - factories have been destroyed in the past, and they have access to the best materials and equipment, and take the most stringent safety precautions. Some people on the net have also been injured by accidents, and many of them had years of experience and took extremely comprehensive safety measures.

Some knowledge of chemistry and physics is essential - if you didn't do high-school chemistry, get yourself a chemistry textbook and read it. Make sure you understand the basic principles involved for any composition you might be making. It is a good idea to check a recipe out with someone who is experienced in chemistry, to make sure you haven't missed any safety aspect.

If you take the time to find out all the information, and put safety of yourself and others as your highest priority, you will find pyrotechnics an extremely fun and rewarding hobby.

2. Reading rec.pyrotechnics

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Often you will see an interesting composition or method posted to rec.pyrotechnics and the temptation is to run out and try it immediately. However, sometimes information posted will contain errors, or omit important safety aspects. Sometimes people will post methods that they heard from some vague source, or that they think should work but haven't tried.

Leave it for a couple of days to see if anyone on the net responds to it. If not, get a printout of it and read it several times to make sure you are completely familiar with it. If you have any questions or corrections for an article, please don't hesitate to post. People on the net would much rather answer a question that may seem "silly" to you, than to have you get hurt.

3. Posting to rec.pyrotechnics

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If you have a composition or a method that has served you well, please share it with the net. Also if you have a question, people will be happy to help you out with it.

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However, please remember that your message is going to be read by a lot of people around the world, many of whom may not be as familiar with aspects of your posting as you are. Include all relevant safety information, for example possible mixing and storage hazards, toxicity, expected behaviour of the composition once ignited etc.

If you post something you haven't tried, be sure to make that clear in your article. This is a good idea when asking questions as well - make sure it is obvious that you are asking a question, rather than posting something you don't know about and hoping someone will correct it.

Read through your article before posting it to make sure that you have covered every aspect, and that there are no errors or ambiguities that could cause people to interpret part of it the wrong way.

4. Legal Aspects of Pyrotechnics

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Chances are that many of the procedures involved in pyrotechnics are illegal without a permit where you live. There are generally separate laws regarding storage of chemicals, manufacture of fireworks, manufacture of explosives, storage of fireworks, storage of explosives, use of fireworks and use of explosives.

The laws regarding fireworks may also be split up in terms of the "Class" of fireworks concerned - commonly available fireworks are Class C, while the fireworks typically seen at displays will be mainly Class B, with some Class C. Make sure you know where you stand in terms of the law in your area, and get a permit if necessary.

Make sure that what you are doing will not cause any damage to other people's property, and that there are no innocent bystanders that can get hurt. There are plenty of laws relating to injury or damage to third parties and their property, not to mention lawsuits. We don't want anyone to get in trouble with the law because of anything here.

5. PGI - Pyrotechnics Guild International

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Pyrotechnics Guild International, Inc is a non-profit organization of professional and amateur fireworks enthusiasts: builders, shooters & watchers.

Membership includes a quarterly journal and an annual convention.

(Idaho (Fire) Falls, Idaho, 92)

For membership information, contact:

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PGI
Ed Vanasek
18021 Baseline Ave
Jordan, MN
55352

You need either three recommendations from random people or one recommendation from a PGI member. Dues are \$25/yr., US.

Another newsletter is American Fireworks News, monthly, miscellaneous news, technical articles, ads, \$19.95/yr.

AFN
Star Rt Box 30
Dingmans Ferry, PA
18328

6. Pyrotechnic Literature =====

6a. Fireworks Literature -----

These are extremely good books on the subject of pyrotechnics, and are really a must-read for the serious pyrotechnics enthusiast. Many others that are not listed here are also worth reading - check out your local library, Books In Print, Pyrotechnica Publications etc. for more references.

Conkling, John A.: "Chemistry of Pyrotechnics: Basic Principles & Theory" (Marcel Dekker, New York, NY 1986. (ISBN 0-8247-7443-4).)

See also Conkling's articles in Scientific American (July 1990, pp96-102) and Chemical & Engineering News (June 29, 1981, pp24-32).

Shimizu, Takeo: "Fireworks - The Art, Science and Technique", 2nd ed. (Pyrotechnica Publications, 1988. (ISBN 0-929388-04-6).)

Lancaster, Ronald: "Fireworks, Principles and Practice" (Illus.) 2nd ed.

(Chemical Publishing Company Incorporated, 1992. (ISBN 0-8206-0339-2).) The 1st edition is also available, and is much cheaper. The 2nd edition only has about 20 new pages and some minor corrections, but is about \$50 more expensive.

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Shimizu often directs people to Lancaster rather than giving the detailed information himself.

Weingart, George W.: "Pyrotechnics" (Illus.)
(Chemical Publishing Company Incorporated, 1968. (ISBN 0-8206-0112-8).)

Davis, Tenney L.: "Chemistry of Powder and Explosives"

More references are available from Books In Print.

By far the best source for all books on fireworks is:

Pyrotechnica Publications
2302 Tower Drive
Austin, TX 78703 USA

6b. Fringe Literature

These books usually deal with home-made explosives etc. more than fireworks, and are usually dubious at best. Most are not worth buying, especially if you are more interested in the pyrotechnics field.

Much of the information in them is inherently unsafe - many of the books deal with field-expedient methods, and assume that some casualties are acceptable along the way. If you want to try anything out of one of these, it is a good idea to ask about it on the net or to someone experienced in pyrotechnics or explosives.

"The Anarchist's Cookbook": this is in "Books in Print" so your local bookstore should be able to get you a copy. Alternatively, you can send \$22 (includes postage) to Barricade Books, PO Box 1401, Secaucus NJ 07096. The Anarchist's Cookbook gets a big thumbs down because it is full of inaccurate information.

"Ragnar's Guide to Home and Recreational Use of High Explosives": thumbs down as it is even more inaccurate than The Anarchist's Cookbook.

US Army Technical Manual 31-210 1969 "Improvised Munitions Handbook":
The Improvised Munitions Handbook generally gets okay reviews; it contains a whole bunch of recipes for making explosives etc. out of handy chemicals. You can get it from several sources, gun shows, or for \$5 from Sierra Supply.

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"Poor Man's James Bond Vol. 2": mostly a set of reprints of various books, in small type. It does have Davis' Chem. of Powder and Explosives and what appears to be Vol. 1 and 2 of the Improvised Munitions Handbook series. Vol. 1 of PMJB has a reprint of Weingart's book Pyrotechnics (?)

Here are some sources for the books. Most of these places will send you a catalog with related material.

Loompanics, P.O. Box 1197 Port Townsend, WA 98368.
This company sells a wide selection of fringe books on drugs, explosives, war, survival, etc.
Catalog \$5.

Sierra Supply, PO Box 1390 Durango, CO 81302 (303)-259-1822.
Sierra sells a bunch of army surplus stuff, including technical manuals such as the Improvised Munitions Handbook.
Sierra has a \$10 minimum order + \$4 postage. Catalog \$1.

Paladin Press, P.O. Box 1307 Boulder, CO 80306

Delta Press Ltd, P.O. Box 1625 Dept. 893 El Dorado, AR 71731

Phoenix Systems, P.O. Box 3339, Evergreen CO 80439
Phoenix carries fuse (50 ft/\$9), smoke grenades, tracer ammo, dummy grenades. Catalog \$3.

U.S. Cavalry, 2855 Centennial Ave. Radcliff, KY 40160-9000 (502)351-1164
Sells all kinds of military and adventure equipment.

Thanks to Ken Shirriff, Phil Ngai, Keith Wheeler, Charles Marshall, Gary Hughes, and others.

6c. Net-Available Information

The so-called "gopher files", a collection of 4 introductory files on pyrotechnics, are available using a file transfer client called gopher. The sources for gopher are available via anonymous FTP from boombox.micro.umn.edu in the directory /pub/gopher/ .

You can see what it looks like by telneting to consultant.micro.umn.edu and logging in as "gopher". The pyroguide is in the Gopher system under:

Other Gopher and Information Servers/Fun & Games/Recipes/Misc/Pyrotechnics

These files are quite a good introduction to pyrotechnics, including information on the manufacture of fuses and casings.

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"The Big Book Of Mischief 1.3", commonly abbreviated TBBOM, is available via anonymous FTP from world.std.com, and has the file path:

obi/Mischief/tbbom13.txt.Z

This is generally a compilation of articles from many sources such as 'The Poor Man's James Bond' and from here in rec.pyrotechnics. This also comes under the heading of 'Fringe Literature', as many of the items and methods contained in it are of dubious safety and reliability.

7. Frequently Asked Questions

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Below are descriptions of several things that are frequently asked about on rec.pyrotechnics - they are not generally of much use in fireworks, but they are here to cut down message traffic on these subjects which have been covered many times before.

First though, here are some safety rules. Read these and memorize them.

1. Mix only small batches, especially when trying something out for the first time. Some mixtures, particularly flash powder, will detonate rather than deflagrate (just burn) if enough is present to be self-confining. It doesn't take much to do this. Small amounts of unconfined pyrotechnic mixtures may damage your hands, eyes or face. Larger amounts can threaten arms, legs and life. The hazards are greatly reduced by using smaller amounts. Also be aware that a mixture using finer powders will generally behave MUCH more vigorously than the same mixture made with coarser ingredients. Many of these mixtures are MUCH more powerful than comparable amounts of black powder. Black powder is among the tamest of the pyrotechnician's mixtures.
2. Many of these mixtures are corrosive, many are very toxic, some will react strongly with nearly any metal to form much more unstable compounds. Of the toxics, nearly all organic nitrates have *very* potent vasodilator (heart and circulatory system) effects. Doses for heart patients are typically in the small milligram range. Some can be absorbed through the skin.
3. Keep your work area clean and tidy. Dispose of any spilled chemicals immediately. Don't leave open containers of chemicals on your table, since accidental spillage or mixing may occur. Use only clean equipment.
4. If chemicals need to be ground, grind them separately, never together. Thoroughly wash and clean equipment before grinding another chemical.

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5. Mixing should be done outdoors, away from flammable structures, and where ventilation is good. Chemicals should not be mixed in metal or glass containers to prevent a shrapnel hazard. Wooden containers are best, to avoid static. Always use a wooden implement for stirring. Powdered mixtures may be mixed by placing them on a sheet of paper and rolling them across the sheet by lifting the sides and corners one at a time.
6. Don't store powdered mixtures, in general. If a mixture is to be stored, keep it away from heat sources, in cardboard or plastic containers. Keep all chemicals away from children or pets.
7. Be sure all stoppers or caps, especially screw tops, are thoroughly clean. Traces of mixture caught between the cap and the container can be ignited by friction from opening or closing the container.
8. Always wear a face shield, or at least shatterproof safety glasses. Also wear a dust mask when handling powdered chemicals. Particulate matter in the lungs can cause severe respiratory problems later in life. Wear gloves and a lab apron when handling chemicals. This rule is very important.
9. Make sure there are no ignition sources near where you are working. This includes heaters, motors and stove pilot lights. Above all, DON'T SMOKE!
10. Have a source of water READILY available. A fire extinguisher is best, a bucket of water is the bare minimum.
11. Never, under any circumstances, use metal or glass casings for fireworks. Metal and glass shrapnel can travel a long way, through body parts that you'd rather they didn't.
12. Always be thoroughly familiar with the chemicals you are using. Don't just rely on the information provided with the recipe. Look for extra information - the Merck Index is very good for this, especially regarding toxicity. It can also provide pointers to journal articles about the chemical.
13. Wash up carefully after handling chemicals. Don't forget to wash your ears and your nose.
14. If a device you build fails to work, leave it alone for half an hour, then bury it. Commercial stuff can be soaked in water for 30 minutes after being left for 30, then after 24 hours cautious disassembly can be a valid learning experience. People have found "duds" from shoots that took place over a year ago, having been exposed to rain etc,

which STILL functioned when fitted with fresh fuse or disposed of in a bonfire. Even after a 30 minute waiting period (minimum), initial pickup should be with a long- handled shovel.

15. Treat all chemicals and mixtures with respect. Don't drop them or handle them roughly. Treat everything as if it may be friction- or shock-sensitive. Always expect an accident and prepare accordingly, even if all these safety precautions are observed. Several people on the net have gotten stitches, lost fingers, or been severely burned. Some of them were very scrupulous in their safety precautions and had many years' safe experience with pyrotechnics.

7a. Nitrogen Tri-Iodide, NI₃.NH₃

Nitrogen Tri-Iodide is a very unstable compound that decomposes explosively with the slightest provocation. It is too unstable to have any practical uses, but is often made for its novelty value. Some books describe uses for it in practical jokes etc. but in my experience it has been far too unstable for this to be a feasible idea. Despite its common name, the explosive compound is actually a complex between nitrogen tri-iodide and ammonia, NI₃.NH₃ (nitrogen tri-iodide monamine).

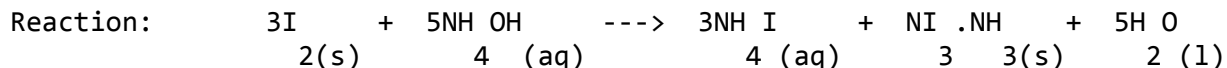
Reagents:

Solid Iodine (I₂)

Ammonia solution (NH₄OH) - Use only pure, clear ammonia. Other solutions, such as supermarket 'cloudy' ammonia, will not give the desired product.

Place a few fine crystals of iodine in a filter paper. The best way to make fine iodine crystals is to dissolve the iodine in a small quantity of hot methanol (care: methanol is toxic and flammable. Heat on a steam bath away from open flame. Use in a well-ventilated area.), and then pour the solution into a container of ice-cold water. This will cause extremely fine iodine crystals to precipitate out. Drain off the liquid and wash the crystals with cold water. If this method is not possible, crush the iodine as finely as possible.

Then filter ammonia through the iodine crystals. Use a small amount of ammonia and refilter it, to reduce wastage. The smaller the pieces of iodine the better the result, as more iodine will react if it has a greater surface area. You will be able to recognise the NI₃.NH₃ by its black colour, as opposed to the metallic purple of the iodine.



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When the $\text{NI}_3 \cdot \text{NH}_3$ decomposes it will leave brown or purple iodine stains. These are difficult to remove normally, but can be removed with sodium thiosulphate solution (photographic hypo). They will fade with time as the iodine sublimates.

Safety aspects:

$\text{NI}_3 \cdot \text{NH}_3$: Despite the common misconception presented in many articles on $\text{NI}_3 \cdot \text{NH}_3$, it is NOT safe when wet. I have personally witnessed $\text{NI}_3 \cdot \text{NH}_3$ exploding while at the bottom of a 1000ml plastic beaker full of water. $\text{NI}_3 \cdot \text{NH}_3$ can not be relied on not to decompose at any time. Even the action of air wafting past it can set it off.

If you want to dispose of some $\text{NI}_3 \cdot \text{NH}_3$ once you have made it, it can be reacted safely with sodium hydroxide solution. $\text{NI}_3 \cdot \text{NH}_3$ is a potent high explosive, and should be treated with respect. Its power, instability and unpredictability require that only small batches be made. Do not make more than you can immediately use. Never attempt to store $\text{NI}_3 \cdot \text{NH}_3$.

The detonation of $\text{NI}_3 \cdot \text{NH}_3$ releases iodine as a purple mist or vapour. This is toxic, so avoid breathing it. Toxicity data on $\text{NI}_3 \cdot \text{NH}_3$ is unknown, but I think it is safe to assume that eating or touching it would be a bad idea anyway.

Iodine: Iodine sublimates easily at room temperature and is toxic - ingestion of 2-4g of iodine can be fatal. Make sure you are in a well-ventilated area, and avoid touching the iodine directly.

Ammonia: Again, use in a well-ventilated area as ammonia is not particularly pleasant to inhale. Ammonia is corrosive, so avoid skin contact, especially if using relatively concentrated solution. If skin contact occurs, wash off with water. Don't drink it.

7b. Thermite

The thermite reaction is a redox reaction that produces a lot of heat and light. In its usual configuration, temperatures can exceed 3000 degrees C, and molten iron is produced. It is therefore mainly used for welding, and by the Army in incendiary grenades.

There are many possible configurations - basically it is the reaction between a reactive metal and the oxide of a less reactive metal. The most

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common is as follows:

Aluminium powder, Al (coarse)	1 volume part or 3 weight parts
Iron (III) Oxide, Fe ₂ O ₃	1 volume part or 1 weight part

A stoichiometric mixture will provide best results.

The powders are mixed together and ignited with a suitable fuse. Many people use magnesium ribbon - I don't recommend this, as magnesium ribbon is not all that easy to light, and quite prone to going out due to oxygen starvation. A much better fuse for thermite is a common sparkler. The mixture should be shielded with aluminium foil or similar to prevent sparks from the sparkler igniting the thermite prematurely.

Reaction:
$$2\text{Al (s)} + \text{Fe}_2\text{O}_3\text{(s)} \rightarrow 2\text{Al}_2\text{O}_3\text{(s)} + 2\text{Fe (l)} + \text{lots of heat}$$

The mixture can be varied easily, as long as the metal oxide you are using is of a less reactive metal than the elemental one you are using, e.g. copper oxide and zinc. Adjust the ratios accordingly.

Safety aspects:

Reaction: Make sure you no longer need whatever you are igniting the thermite on - the reaction will melt and/or ignite just about anything. If you ignite the thermite on the ground, make sure the ground is DRY and free of flammable material. If the ground is wet a burst of steam may occur, scattering 3000 degree metal everywhere.

Be careful when igniting the thermite - use adequate shielding to prevent premature ignition. Don't get close to the mixture once ignited - it has been known to spark and splatter. Don't look at the reaction directly. It produces large amounts of ultraviolet light that can damage the eyes. Use welder's goggles, 100% UV filter sunglasses or do not look at all.

Aluminium: Chemical dust in the lungs is to be avoided. As always, wear a dust mask. Make sure the environment you are working in is dry - aluminium powder can be dangerous when wet. Fine aluminium dust is pyrophoric - this means it can spontaneously ignite in air. For this reason aluminium powder with a large particle size is recommended.

Iron Oxide: This is not directly toxic, but any particulate matter in the lungs is not good. Again, the dust mask is important.

7c. Dry Ice Bombs

Dry ice bombs are devices that use pressure to burst a container, producing a loud report and limited shock effects. No chemical reaction is involved - the container, usually a plastic 2-litre soft drink bottle, is burst by the physical reaction of solid carbon dioxide, CO₂, subliming into gas. As the CO₂ sublimes, the pressure builds up and eventually the container ruptures.

The method is very simple - some dry ice is added to the container, some water is added (about 1/3-1/4 full) and the cap is screwed on tight. Within a short time the container will burst, usually extremely loudly. The water can be omitted if a longer delay time is required. It is reported that these devices can be manufactured using liquid nitrogen instead of dry ice, and no water. This is not recommended as the delay time will be substantially shorter.

Safety aspects:

Device: NEVER use glass or metal containers! I cannot stress this enough. Dry ice bombs are extremely unpredictable as to when they will go off, and a glass or metal container is very very dangerous to both the constructor and anyone else in the vicinity. Plastic bottles are much safer because the fragments slow down quicker, and thus have a smaller danger radius around the device. Plastic fragments are still very nasty though - don't treat the device with any less caution just because it is made of plastic.

There is no way to tell how long you have until the dry ice bomb explodes - it can be anywhere from a few seconds to half an hour. Never add the water or screw the cap on the container until you are at the site you want to use it and you are ready to get away.

Never go near a dry ice bomb after it has been capped. If a dry ice bomb fails to go off, puncture it from long range with a slingshot, BB gun, by throwing stones at it or similar. Some indication of timing can be achieved by semi-crushing the container before capping - once the container has expanded back to its original shape it is no longer safe to be anywhere near.

Don't forget that the temperature of the day and the size of the dry ice pieces will affect the delay length - don't assume that delay times will be similar between bombs. A hotter day or smaller pieces of dry ice (i.e. greater surface area) will create a shorter delay. Remember, even though no chemical reaction

occurs you can still be legally charged with constructing a bomb.

Dry Ice: Humans will suffocate in an atmosphere with a carbon dioxide concentration of 10% or more. Use in a well-ventilated area. Dry ice typically has a temperature of about -75 degrees C, so do not allow it to come into contact with the skin, as freezer burns and frostbite will occur. Always use gloves or tongs when handling dry ice.

7d. Smoke Bombs

A relatively cheap and simple smoke mixture is potassium nitrate (saltpetre) and sugar. The mixture can be used in powder form, but much better results are achieved by melting the components together. The mixture should be heated slowly until it just melts - beware of excessive heating as the mixture will ignite. Keep a bucket of water next to you in case the mixture does ignite, and perform the entire operation outdoors if possible.

The mixture does not have to be completely liquid, the point at which it has about the viscosity of tar or cold honey is about right. While it is semi-liquid it can be poured into cardboard or clay molds, and a fuse inserted. Once it cools and hardens it will be similar to a stick of hard candy, hence its common name of "caramel candy".

Safety aspects:

Mixture: The mixture burns very hot. Don't go near it once ignited, and don't assume that whatever the mixture is contained in or standing on will survive. Try not to breathe the smoke as fine particles in the lungs are not good for them.

7e. Basic Pyrotechnic Devices

Stars

A star is an amount of pyrotechnic composition that has by some means been fashioned into a solid object. These are the bright burning objects you see ejected from Roman candles, shells, mines etc.

Usually the pyrotechnic composition is mixed with a binder and a small amount of solvent to make a doughy mass which is then fashioned into stars, although some use has been made of so-called pressed stars, which involve the composition being pressed extremely hard into a mold with a

hydraulic press or similar, thus doing without the solvent.

The usual methods are to make the composition into a flat pancake or sausage and cut it up into stars ("cut stars"), pushing it through a tube with a dowel, cutting it off at regular intervals ("pumped stars") or rolling cores of lead shot coated in fire clay in a bowl of the composition ("rolled stars").

Cutting and pumping produce cubic or cylindrical stars, while rolling produces spherical stars. Pumped stars are the most suitable for Roman candles, because it is easy to get the correct width. The stars are often dusted with a primer, usually meal black powder, to ensure ignition.

Shell

The shell is a sphere or cylinder of papier mache or plastic which contains stars and a bursting charge, together with a fuse. It is fired into the air from a tube using a lift charge, usually black powder. The time the fuse takes determines the height above the ground at which the shell will burst, igniting and spreading the stars.

Rocket

A rocket consists of a tube of rocket fuel, sealed at one end, with a constriction, or nozzle, at the other end. The burning fuel produces exhaust gases, which, when forced out the nozzle, produce thrust, moving the rocket in the other direction.

Solid fuel rockets can be one of two types - end-burning, where the fuel is solidly packed into the tube, so the fuel can only burn at one end - and core-burning, where there is a central core longitudinally through the fuel, so the fuel can burn down its full length. At the top of the rocket can be a smoke composition, so it is possible to determine the maximum height ("apogee") of the rocket, or a burst charge and stars.

Lance

A lance is a thin paper tube containing a pyrotechnic composition. These are most commonly used in large numbers to make writing and pictures at fireworks shows - this is referred to as lancework. The tube is thin so burns completely away as the lance burns, so as not to restrict light emission from the burning section.

Gerb

These are pyrotechnic sprays, often referred to as fountains or flower-pots. They consist of a tube full of composition, sealed at one end and with a nozzle at the other, similar to a rocket. Unlike a rocket, they are not designed to move anywhere, so all the emphasis is on making the nozzle exhaust as long as pretty as possible, with large amounts of sparks, nice colours etc.

The sparks are produced by metal powders or coarse charcoal in the gerb composition, with coarse titanium powder being the chemical of choice. Gerb compositions in a thin tube set up in a spiral arrangement are used as wheel drivers, for spinning fireworks e.g. Catherine wheels.

Waterfall

These are similar to gerbs, but usually do not spray as far. They are usually mounted horizontally in banks of several tubes, placed some distance above the ground. When ignited, the effect is like a brilliant waterfall of sparks.

Mine

These have a mortar arrangement similar to that for a shell, but are not designed to send out a shell. The lift charge sends up a bag full of stars and a bursting charge, with a short fuse set to spread the stars relatively close to the ground. Because the bag has much less strength than a shell, the stars are not spread as far, and the final effect is that of a shower of stars moving upward in an inverted cone formation.

7f. Terminator Bombs, MacGyver, etc.

The first thing to remember when watching pyrotechnics in movies, TV shows etc. is that it is exactly that, not real life. There is almost always no point in trying to extrapolate what MacGyver, for example, does back to reality, with respect to pyrotechnics at least. Reese making those bombs from supermarket supplies in Terminator was bogus, as are pretty much any information on explosives you receive from movies. Sorry.

8. Commonly Used Chemicals in Pyrotechnics

Ignitibility and Reactivity

The secret of making a good pyrotechnic mixture is homogeneity. The better the contact with the oxidiser and the fuel is, the fiercer the composition. Finely ground fuels and oxidisers are essential for good stars and propellants. The required intimacy also implies that mixing can never be thorough enough.

For consistent results, use the same sieves and same mixing methods. Wet mixing is sometimes more efficient than stirring the dry composition; moreover, it is almost always safer. Star compositions and granulated powders can almost always be mixed with water or some other solvent.

Good, homogenous compositions also ignite more easily. Large amounts of loose, fine powder of almost any pyrotechnic composition represent a large fire and explosion hazard. But when such a powder is kneaded and cut into stars or carefully pressed in a tube, it will take fire easily and burn smoothly.

This is the pyrotechnist's dilemma: the best compositions are often the most dangerous ones, too. But not always. There are chemicals and compositions with much worse safety records than today's compositions have. In the list of pyrotechnic chemicals below, the most notorious ones have been indicated.

Aluminium, Al -- Fuel

This is used in many compositions to produce bright white sparks or a bright white flame. There are many grades of aluminium available for different spark effects. Most pyrotechnic compositions that involve sparks use aluminium, e.g. sparklers, waterfalls etc.

Ammonium Nitrate, NH_4NO_3 -- Oxidiser

This is used very infrequently in pyrotechnics due to its hygroscopic nature and the fact that it decomposes even at relatively low temperatures. Even when dry, it reacts with Al, Zn, Pb, Sb, Bi, Ni, Cu, Ag and Cd. In the presence of moisture it reacts with Fe. It reacts with Cu to form a brisant and sensitive compound. It is best not to use any

bronze or brass tools when working with ammonium nitrate.

Ammonium perchlorate, NH_4ClO_4 -- Oxidiser

Used as an oxidiser in solid rocket fuels, most notably the solid booster rockets for the Space Shuttle. Using it in a composition improves the production of rich blues and reds in the flames. As with any ammonium salt, it should not be mixed with chlorates due to the possible formation of ammonium chlorate, a powerful and unstable explosive.

Anthracene, $\text{C}_{14}\text{H}_{10}$ -- Smoke Ingredient

Used in combination with potassium perchlorate to produce black smokes.

Antimony, Sb -- Fuel

The metal is commonly used in the trade as 200-300 mesh powder. It is mainly used with potassium nitrate and sulphur, to produce white fires. It is also responsible in part for the glitter effect seen in some fireworks.

Antimony trisulphide, Sb_2S_3 -- Fuel

This is used to sharpen the reports of pyrotechnic noisemakers, e.g. salutes. It is toxic and quite messy.

Barium salts -- Colouring Agents

Used to colour fires green. several are used:

Barium carbonate, BaCO_3 -- Colouring Agent, Stabilizer

As well as being a green flame-colourer, barium carbonate acts as a neutralizer to keep potentially dangerous acid levels down in pyrotechnic compositions.

Barium chlorate, $\text{Ba}(\text{ClO}_3)_2 \cdot 2\text{H}_2\text{O}$ -- Colouring Agent, Oxidiser

Used when deep green colours are needed. It is one of the more sensitive chemicals which are still used, best to avoid if possible, but if used it should be in combination with chemicals which will reduce its sensitivity.

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Barium nitrate, $\text{Ba}(\text{NO}_3)_2$ -- Colouring Agent/Enhancer, Oxidiser

Not very strong green effect. Used with aluminium powder to produce silver effects. Below 1000C aluminium burns silvery-gold, characteristic of aluminium-gunpowder compositions. Above 1000C it burns silver, and may be achieved using barium nitrate. Boric acid should always be used in compositions containing barium nitrate and aluminium.

Barium oxalate, BaC_2O_4 -- Colouring Agent

Sometimes used, generally in specialised items with magnesium.

Boric acid, H_3BO_3 -- Stabilizer

This is a weak acid, often included in mixtures that are sensitive to basic conditions, notably those containing aluminium.

Calcium carbonate, CaCO_3 -- Stabilizer

Used as a neutralizer in mixtures that are sensitive to both acids and bases, for example chlorate/aluminium flashpowder.

Calcium oxalate, CaC_2O_4 -- Colour Enhancer

Used to add depth to colours produced by other metal salts.

Carbon black/Lampblack, C -- Fuel

A very fine form of carbon made by incompletely burning hydrocarbon fuels. Commonly used in gerbs to produce bright orange sparks.

Charcoal, C -- Fuel

Probably the most common fuel in firework manufacture, it is not pure carbon and may contain in excess of 10% hydrocarbons. Indeed, the purer carbon charcoals (e.g. activated charcoal) do not necessarily give better results, and are very often worse than less pure grades. It is included in the vast majority of pyrotechnic compositions in various mesh sizes and grades, or as a component of black gunpowder.

Clay

This is an important material for making fireworks, not as a reagent but to perform various practical applications such as blocking or constricting the ends of tubes for crackers or rocket nozzles, or coating lead shot prior to the application of star composition when making rolled stars.

Copper and copper compounds -- Colouring Agents

Used to add both green and blue colours to flames:

Copper metal, Cu -- Colouring Agent

Both the bronze and electrolytic forms are occasionally used, but easier methods are available for the same effect.

Copper acetoarsenate, $C_4H_6As_6Cu_{40}I_6$ -- Colouring Agent

Commonly called Paris Green, this chemical is toxic but used to produce some of the best blue colours in combination with potassium perchlorate.

Copper carbonate, $CuCO_3$ -- Colouring Agent

This is the best copper compound for use with ammonium perchlorate for production of blue colours. Also used in other blue compositions.

Copper (I) chloride, $CuCl$ -- Colouring Agent

Cuprous chloride is probably the best copper compound for creating blue and turquoise flames, and it can be used with a variety of oxidizers. It is non-hygroscopic and insoluble in water, but it is oxidised slowly in air.

Copper oxides, CuO/Cu_2O -- Colouring Agent

Used for many years for blues, but needed mercury chloride to intensify colours. Seldom used.

Copper oxychloride -- Colouring Agent

Occasionally used in cheap blue compositions.

Cryolite, Na_3AlF_6

-- Colouring Agent

Also known as Greenland spar, this is an insoluble sodium salt. Sodium salts are used to produce yellow colours, but as sodium salts generally absorb water this tends to be a problem. By using cryolite this problem is surmounted.

Dextrin

-- Binder

Dextrin is a type of starch that is added to many firework mixtures to hold the composition together. It is the most commonly used binder in pyrotechnics.

Gallic acid (3,4,5-trihydroxybenzoic acid)

This is used in some formulas for whistling fireworks. Whistle mixes containing gallic acid are generally the most sensitive of the whistling fireworks, with high sensitivity to both friction and impact when used with chlorates, but cannot be used with perchlorates either. There are safer alternatives for whistle compositions.

Gum arabic (Gum Acacia)

-- Binder

An example of the various wood-resin-based adhesives used to bind firework compositions. Others used include Red Gum and Gum Copal.

Gunpowder

Black powder is the mainstay of pyrotechnics. At a basic level it is a mixture of potassium nitrate, charcoal and sulphur. However, simply mixing these ingredients together will not produce proper black powder. It merely produces a much milder version, which itself is used

extensively in pyrotechnics, and is commonly called meal powder.

True black powder takes advantage of the extreme solubility of potassium nitrate by mixing the very fine milled ingredients into a dough with water, then using strong compression to force the water out of the mixture, so that tiny crystals of potassium nitrate form in and around the particles of the other ingredients. This produces a product that is far fiercer than the simple meal powder.

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Hexachlorobenzene, C₆Cl₆ -- Colour Enhancer

Used as a chlorine donor in coloured compositions that require one. Rarely used, with PVC, Saran and Parlon being preferred.

Hexachloroethane, C₂Cl₆ -- Smoke Ingredient

The basic ingredient in many military smoke formulas. Not often used with inorganic smoke mixtures, except those containing zinc.

Iron, Fe -- Fuel

The metal filings are used mainly in gerbs to produce sparks. Iron will not keep well in firework compositions, and so it is generally pre-coated with an oil/grease. One simple method is to add 1 gram of linseed oil to 16 grams of iron filings, mix, and boil off the excess oil.

Linseed oil -- Stabilizer

Used to coat metal powders in order to prevent them from oxidation, both prior to use and in the firework composition. Polyesters are used in commercial fireworks, but linseed oil remains an accessible option to the amateur.

Lithium carbonate, Li₂CO₃ -- Colouring Agent

Used to colour fires red. It has no advantage over strontium salts for the same purpose.

Magnesium, Mg -- Fuel

Used to produce brilliant white fires. Should be coated with linseed oil/polyester resin if contained in a composition which is not to be used immediately, as it may react with other components of the mixture. The coarser magnesium turnings are sometimes used in fountains to produce crackling sparks. Magnesium-aluminium alloys give similar effects, and are rather more stable in compositions.

Parlon -- Colour Enhancer, Binder

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Parlon is a chlorine donor, and a key ingredient in many coloured stars. It is a chlorinated isoprene rubber, chlorine content 66%. It interferes with burning less than PVC or saran, and can be used as a binder. It is soluble in methyl ethyl ketone (MEK) and partially in acetone. Compositions made with parlon and acetone or MEK are nearly waterproof.

Phosphorus, P -- Fuel

Phosphorus is rarely used in pyrotechnics today, except for a few specialized applications. It was used commonly many years ago, but as the hazards associated with its use became known it dropped out of use.

Phosphorus comes in several forms, of which the red and the white/yellow varieties were used. Red phosphorus (used in the strikers on the side of matchboxes) is the more stable form, while white phosphorus (used by the military in incendiary devices) ignites spontaneously in air, and must therefore be stored under water or otherwise protected from the atmosphere. Both forms are toxic.

Polyvinylchloride (PVC) -- Colour Enhancer, Binder

PVC is a commonly used chlorine donor. It is not as good as Parlon for this purpose, but is cheaper and more readily available. PVC is soluble in tetrahydrofuran (THF) but almost all other solvents are useless. Methyl ethyl ketone (MEK) will plasticise PVC to some extent, however.

Potassium benzoate, C6H5C02K -- Fuel

Used in whistling fireworks, in combination with potassium perchlorate. It must be very dry for this purpose, and should be less than 120 mesh.

Potassium chlorate, KClO3 -- Oxidiser

Originally used very commonly in pyrotechnics, potassium chlorate has gradually been phased out due to its sensitivity, in favor of potassium perchlorate. Mixtures containing potassium chlorate and ammonium salts, phosphorus or anything acidic are particularly dangerous. For this reason mixtures containing potassium chlorate and sulphur are to be avoided, as sulphur (especially the common "flowers" of sulphur) may contain residual amounts of acid that can sensitize the mixture. In general, potassium chlorate should be avoided unless absolutely necessary.

Chlorates have probably caused more accidents in the industry than all other classes of oxidisers together. The reason lies in their sensitivity

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to acids and their low decomposition temperature. When mixed with an easily ignitable fuel, such as sugar or sulfur, chlorates will ignite from a fingernail striking a wire screen. Moreover, sulfur is often acidic, a fact that has led to spontaneous ignition of sulfur-chlorate compositions. If you intend to use chlorates, pay extra attention to safety.

Potassium nitrate, KNO_3 -- Oxidiser

A very common oxidising agent in pyrotechnics, potassium nitrate is one of the chemicals you should never be without. From its essential use in gunpowder to general applications in most fireworks, you will find potassium nitrate used wherever a relatively mild oxidiser is required. In fireworks it should pass 120 mesh, but can be used at 60 mesh. The fine powder should be used as soon as possible after grinding or milling as it will soon cake and have to be re-ground.

Potassium perchlorate, KClO_4 -- Oxidiser

More expensive than potassium chlorate, but a better oxidising agent and far safer. In almost all mixtures that previously required the chlorate, safety factors have led to its replacement with potassium perchlorate. It should be used in place of the chlorate wherever possible.

Potassium picrate

This is a shock sensitive compound that is used in some whistle formulas. While safer than gallic acid formulas in this respect, care should be taken to keep it away from other metals such as lead, because some other metallic picrates are extremely sensitive.

Saran -- Colour Enhancer, Binder

Saran is another plastic chlorine donor. It is most commonly encountered in the form of the cling wrap used to protect foodstuffs. It is slightly soluble in tetrahydrofuran (THF) and will be plasticised by methyl ethyl ketone (MEK).

Shellac -- Binder

Shellac is an organic rosin commonly used as a binder where a water-soluble binder would be inappropriate. It can be bought at hardware stores in the form of lustrous orange flakes, which can be dissolved

Sodium salts are sometimes used in place of the corresponding potassium salts, but this is uncommon due to their hygroscopic nature. They rapidly absorb water from the air, which can ruin a pyrotechnic composition. In particularly dry environments they can be used without too much trouble, and are therefore used in places like Egypt due to the relative cheapness of some of the salts with respect to the potassium ones. Sodium salts are also used as colourising agents, producing a characteristic orange flame.

Used to colour flames a brilliant red:

Used often for producing red colours, and as a fire retardant in gunpowder mixtures.

As for strontium carbonate, generally, but suffers from greater water content.

This is the most commonly used strontium salt, because it provides the most superb red colour available. Best results will be achieved if the strontium nitrate is anhydrous.

Another basic fuel in pyrotechnics, sulphur is used in many pyrotechnic formulas across the range of fireworks, most obviously in black powder. It is recommended to avoid the common "flowers" of sulphur, as they contain residual acid. If they cannot be avoided, a small amount of a neutralizer such as calcium carbonate should be added if acid is likely to present a problem.

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Titanium, Ti -- Fuel

The coarse powder is safer than aluminium or magnesium for producing sparks, and gives rise to beautiful, long, forked blue/white sparks. Fantastic for use in any spark composition, especially gerbs.

Petroleum jelly (Vaseline) -- Stabilizer

Very occasionally used to protect metal powders e.g. iron by coating them with a thin film of petroleum jelly.

Zinc, Zn -- Fuel, Smoke Ingredient

Zinc metal is used in what are known as zinc spreader stars, which produce a very nice effect that looks like a green glowing cloud. Also used in several smoke formulas, due to the thick clouds of zinc oxide that can be produced.

SPECIAL CAVEATS

AVOID:

Mixing chlorates with: acidic ingredients
sulphur or sulphides
ammonium salts
phosphorus
pitch or asphalt
gum arabic solution.

Mixing picric acid with: lead or lead compounds
almost any other metal.

Mixing ammonium nitrate with metals especially copper.

Mixing nitrates with aluminium WITHOUT boric acid.

Further Information

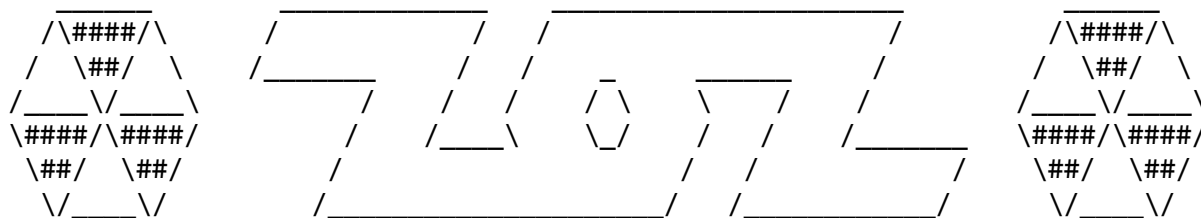
Further information about these chemicals, for example chemical, physical and toxicity data, can be obtained from the following books:

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The Merck Index
The CRC Handbook of Physics and Chemistry
Ullmann's Encyclopaedia of Industrial Chemistry
Kirk-Othmer's Encyclopaedia of Chemical Technology

The information may be found elsewhere, but these are the most comprehensive and readily available.

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