



A SYNTHESIS-BASED APPROACH TO OVER THE COUNTER PYROTECHNIC COMPOSITION

An Over the Counter Composition Repository,
Chemical Sourcing and Synthesis Guide

For a number of years now, I've been attempting to move towards a set of compositions and devices that can be manufactured using only chemicals and materials purchased and synthesised from over the counter products. What follows is a collection of information on how I do this. The information here can mostly not be attributed to me and is simply a compilation of the research I have done. Where possible, I have given reference to the individuals whose hard work has allowed me to get to this point.

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Over the Counter Pyrotechnic Compositions

Black Powder

Potassium Nitrate (75 Parts)

Lump Charcoal (15 Parts)

Sulphur (10 Parts)

+ Dextrin (5 Parts)

Nozzleless Black Powder Rocket Fuel

Potassium Nitrate (75 Parts)

Lump Charcoal (15 Parts)

Sulphur (10 Parts)

+ 80 Mesh Charcoal (5 Parts)

Granulate either with water or with mineral oil and lacquer thinner through a 20 Mesh screen. Dry before use.

Nozzled Black Powder Rocket Fuel (Richard Wolter)

Potassium Nitrate (60 Parts)

Lump Charcoal Air-float (10 Parts)

Horticultural Charcoal 80 Mesh (18 Parts)

Horticultural Charcoal 36 Mesh (2 Parts)

Sulphur (10 Parts)

Mill together the KNO_3 , Sulphur and air-float charcoal for 30 minutes then integrate remaining charcoal before granulating either with water or with mineral oil and toluene through a 20 Mesh screen. Dry before use.

Nitrate Based Slow Flash

Air-float Potassium Nitrate (50 Parts)

Dark Aluminium Powder (30 Parts)

Air-float Sulphur (20 Parts)

Simple Chlorate Flash

Air-float Potassium Chlorate (60 Parts)

Dark Aluminium Powder (30 Parts)

Air-float Sulphur (10 Parts)

This composition is extremely dangerous. Before even considering its use, consult with an experienced pyrotechnician. If you choose not to, remember, natural selection halts for no man.

D1 Glitter

Potassium Nitrate (53 Parts)

Horticultural Charcoal (11 Parts)

Sulphur (18 Parts)

Spherical Aluminium (7 Parts)

Sodium Bicarbonate (7 Parts)

Dextrin (5 Parts)

Chrysanthemum 6

Potassium Nitrate (55 Parts)

Horticultural Charcoal (33 Parts)

Sulphur (7 Parts)

Dextrin (5 Parts)

Chrysanthemum 6 Extra (Modified by Ned Gorski)

Potassium Nitrate (55 Parts)

Horticultural Charcoal (33 Parts)

Sulphur (7 Parts)

Dextrin (5 Parts)

+ 36 Mesh Charcoal (10 Parts)

Chrysanthemum of Mystery

Potassium Nitrate (50 Parts)

Horticultural Charcoal (45 Parts)

Dextrin (5 Parts)

Shimizu's Tiger Tail

Potassium Nitrate (44 Parts)

Horticultural Charcoal (44 Parts)

Sulphur (6 Parts)

Dextrin (6 Parts)

Bill Ofca's Gold Spider Web

Potassium Nitrate (54 Parts)

Horticultural Charcoal (32 Parts)

Sulphur (7 Parts)

Dextrin (7 Parts)

Simple Nitrate White

Potassium Nitrate (50 Parts)

Spherical Aluminium (30 Parts)

Sulphur (20 Parts)

+ Dextrin (4 Parts)

Lancaster Chlorate Red

Potassium Chlorate (70 Parts)

Strontium Carbonate (15 Parts)

Red Gum (10 Parts)

Horticultural Charcoal (1 Part)

Dextrin (4 Parts)

Pihko Yellow Star #1

Potassium Chlorate (60 Parts)

Sodium Bicarbonate (20 Parts)

Dextrin (20 Parts)

Adapted Pihko Orange

Potassium Chlorate (60 Parts)

Calcium Carbonate (20 Parts)

Dextrin (20 Parts)

Lancaster Green Star #1

Potassium Chlorate (28 Parts)

Barium Chlorate (53 Parts)

Red Gum (10 Parts)

Horticultural Charcoal (5 Parts)

Dextrin (4 Parts)

50AE Chlorate Blue #2

Potassium Chlorate (67 Parts)

Copper Oxychloride (13 Parts)

Shellac (5 Parts)

Polyvinyl Chloride (8 Parts)

Dextrin (4 Parts)

50AE Chlorate Magenta #1

Potassium Chlorate (67 Parts)

Copper Oxychloride (7 Parts)

Strontium Carbonate (6 Parts)

Shellac (4 Parts)

Polyvinyl Chloride (6 Parts)

Dextrin (4 Parts)

Black Powder Prime

Potassium Nitrate (75 Parts)

Horticultural Charcoal (15 Parts)

Sulphur (10 Parts)

+ Dextrin (5 Parts)

+ Spherical Aluminium (5 Parts)

+ Red Iron Oxide (5 Parts)

I would like to conclude this section by noting two things. Firstly, the list above is by no means expansive. Especially considering the charcoal streamers and glitters contained in this list, there are undoubtedly many more compositions that would fit here. This list is merely those which I use on a regular basis. This is also true for the colour compositions listed. If you feel there is a specific composition which would fit well in this list, feel free to contact me via email or on various forums as I would love to hear of it. Secondly, the information given in the above list is not adequate as either safety or preparation notes. Much important information has been omitted for the sake of being concise. Further research will be necessary before attempting to manufacture any of these compositions.

OTC Chemical Sourcing and Synthesis

Preface: Although all the chemicals in the above compositions and those which are described and produced below are from OTC sources, to say they are easy to acquire and produce is inaccurate. Personally, I have managed to locate all these chemicals and chemical precursors and perform all the reactions listed below with only OTC chemicals. However, depending on your location and proficiency in chemistry, your success may vary.

Further to this, much of the information provided in this document is only preliminary and thorough research of the relevant chemistry is required to undertake these syntheses safely and successfully. Having said that, this document is a good repository from which one may begin.

Potassium Nitrate (KNO_3)

Potassium nitrate is often considered the base chemical of pyrotechnics as it is used to make countless compositions; the most vital of which being black powder which is indisputably the most important composition in pyrotechnics. However, KNO_3 is one of the more difficult chemicals to source from this list. Further, no viable synthesis can produce it, meaning the only viable way to procure potassium nitrate is generally accepted to be purchasing it either as a fertiliser, stump decomposing agent (stump remover) or meat preserving agent. However, the latter two of these often come at very high cost. Without a doubt, the most viable source of KNO_3 for amateur pyrotechnicians is purchasing it as a fertiliser. This can sometimes be hard, although, to my knowledge, almost every nation in the world still uses KNO_3 as a fertilising agent and even very strict nations have only completely banned the use of NH_4NO_3 fertilisers.

The first instinct of many when looking for KNO_3 is to head for the local hardware store, however, in almost all cases, it will not be something they stock. What you need to find is a store that specialises in the sale of farm equipment and supplies. Often a google search of "Rural Store," "Farm Store," "Agricultural Store," or "Farmers CO-OP" will turn up one of these suppliers, often located on the outskirts of major cities or in small rural communities. Looking on their websites will often not show the product as being something they stock – for legal reasons – so the best way to find out if they sell it is by calling. When on the phone, instead of asking for potassium nitrate, using brand names will add legitimacy to your call. In Australia, the most common brands stocked are "Haifa Multi-K" and "Krista-K Plus" which is what I ask for when calling a company; if they do not know what you are talking about, you can tell them you are after potassium nitrate.

You will most commonly find 25kg (50lb) bags being sold for around \$50 USD which is a decent price, although, the cost can vary quite a lot. A note to be made on purity: look at the NPK rating on the front of the bag. Pure KNO_3 has an NPK rating of 13.5-0-46.2 which is often given the name 'GG' or 'Green House Grade,' although any grade will work - just look for an NPK rating similar to the one above. Personally, as do many other pyrotechnicians, I use 'Multi-K Classic' with an NPK rating of 13-0-46.

Sulphur/ Sulfur

Sulphur is used primarily as a modifying agent in pyrotechnics and occasionally as a fuel in select compositions. Sulphur is a relatively easy chemical to acquire and can be purchased from a number of sources including pharmacies, hardware stores, and agricultural suppliers. The most economical way of purchasing Sulphur is from the agricultural store as a fungicide in either 25kg (50lb) bags for around \$40 USD or by the kilogram, which is often also an option costing \$3-\$4 USD per kilogram. An alternate option available from the hardware store is 'Dusting Sulphur' which is often sold for around \$15 USD per kilogram. This is in all effectiveness the same product as that available from the other sources, although, it is much more expensive and much finer in particle size.

Charcoal

Charcoal serves as the primary fuel in a large range of pyrotechnic compositions, including black powder, charcoal streamers and charcoal-based glitters such as D1. Charcoal is quite an easy chemical to attain or produce. Around the world, large numbers of amateur pyrotechnicians produce their own charcoal by roasting splints of fresh wood in an anaerobic environment, such as a paint can. The advantage of this process is the knowledge of exactly what wood is contained in the final product, a fact paramount to the production of very high-quality black powder. However, in the search for a less laborious charcoal source, I have managed to locate two sources of OTC charcoal which, when used together, can serve as an adequate alternative to home-produced charcoal in all pyrotechnic compositions I have tested to date. This testing included black powder, star compositions, and rocket fuel.

For use in star compositions and as an additive to produce sparks in rocket fuel, 'Horticultural Charcoal' – available in the gardening section of most hardware stores – is the best option. This charcoal generally costs around \$3 USD per kilogram. In Australia, horticultural charcoal mostly consists of hardwoods such as Red Gum and Iron Bark, although, this does vary between regions and is dependent on local availability. In the US for example, most horticultural charcoal is produced using Oak. Due to the nature of horticultural charcoal, namely in being made almost totally of hardwood, its main failing is in the inability to produce fast-burning black powder such as is needed to break and lift shells. To account for this failing, another common OTC source of charcoal is used instead - lump charcoal.

As previously stated, when the aim is to lift or break shells, horticultural charcoal based black powder does not perform well enough to give the desired results. Instead, 'Lump Charcoal' is used to substitute. Although once a rare sight, in recent years, lump charcoal has grown greatly in popularity due to a raised demand for more organic barbeque fuel options. Once something that had to be sourced from specialist suppliers, lump charcoal is now a staple found in the outdoor living sections of almost all hardware stores. However, some discretion must be taken when purchasing a bag of lump charcoal for use in pyrotechnics. When grilling, the best type of charcoal to use is one which burns and gives off heat for the longest duration, thus, hardwood is the obvious choice. As a result, all high-quality lump charcoals are made from extremely hardwoods to ensure the best cooking results. Conversely, when making black powder, the lowest density wood available is desired and as a result, the best charcoal to select is almost always the cheapest one sold. To get a rough idea of which is best, it is possible to compare the size of the bags used by suppliers. As softwood has a much lower density than hardwood, the same mass of charcoal will take up a much larger space and thus, a bag of softwood will be much larger than a bag of hardwood. What

this means, in practice, is when selecting a brand of charcoal, the best one to select will be the one which is largest for a given weight. The most common size sold in Australia is 10kg (20lb) and that is what I have always used to compare between brands. The one I purchase is the largest for that given mass. Generally though, just buying the cheapest charcoal available is sufficient to ensure that you get the highest quality charcoal for pyrotechnic applications available. Charcoal from this source generally costs about \$2 USD per kilogram.

A note relevant to the processing of charcoal powder into differing grades such as '80 Mesh' or '40 Mesh' for compositions such as rocket fuel, where it is used to give sparks: look online for companies, often based in China, who sell small 30cm by 30cm sheets of screen for only a few dollars each. By simply searching, for example, "60 Mesh Screen" on eBay or Amazon, one is quickly able to find the appropriate screen for a desired purpose. I myself always go 20 mesh over 20 mesh under for screening, thus, if a desired powder is 60 Mesh, I will make -40+80 Mesh powder, which tends to work well. One does have to frame these screens, but this is a trivial exercise considering the usefulness of being able to ascertain a specific mesh of charcoal or any other chemical.

Note also: charcoal briquettes are not a viable source of charcoal and contain several binders and additives that will almost totally destroy the effect of any composition they are used in. Further, I have no information on the safety or incompatibilities of charcoal briquettes and their additives.

Dextrin

Dextrin is used as a binding agent and occasionally a fuel in a large array of pyrotechnic compositions. Dextrin finds some niche uses in arts and crafts as a binder and glue and thus, some have supposed it to be available for purchase through various art store chains. However, I have never seen it being sold for such uses. Instead, one of the most common ways to acquire dextrin is via the baking of pure cornstarch which is also known as corn flour, maize starch or maize depending on where you live.

Many tutorials exist describing this process which is far from complex. Simply placing grocery store cornstarch in the oven at approximately 200°C (400°F) for 4-6 hours rearranges the molecular structure of the starch, converting it into golden brown dextrin. If more information on this process is desired, many articles exist online which are quite easy to find.

Aluminium/ Aluminum Powders

Aluminium is used as both an agent to produce sparks and as a fuel in a number of pyrotechnic compositions. Aluminium powders come in many different grades and are given many different names depending on the size and shape of the particles which make up the powder. Even with all these distinctions, I find that for most uses only two grades of aluminium are needed, 'Spherical 200 Mesh Aluminium' and 'Flake Dark Aluminium.' Below are images of each of these types of powders to show the difference.

Flake Dark Aluminium



Spherical -200 Mesh Aluminium



It is occasionally stated that spherical aluminium powder can be found at art and craft stores, although, such claims are often swiftly shot down by those who have searched to no avail for this elusive chemical. In actuality, it is sold in craft stores, but regular craft stores do not stock aluminium powder. In most cases, it is necessary to find a craft store that specialises in resin casting, cold casting or sculpture. A google search of "Resin casting supplies store" will often turn up several relevant results. Like potassium nitrate, many of these stores do not list aluminium on their websites, so giving them a call is the recommended approach. If they do not supply it, it is likely they will be able to direct you to someone who does. Aluminium from these suppliers cost around \$30 USD per kilogram.

The second major type of aluminium used almost exclusively in flash compositions is 'Fine Flake Aluminium,' which goes by many names, including German Dark Aluminium, Indian Blackhead aluminium or simply dark aluminium powder. All of these have slight differences in quality due to their differing production methods, however, for simple flash boosters and small salutes, these very high-quality aluminiums can be replaced with a home-produced type of dark aluminium, made by milling aluminium foil with charcoal powder in an anaerobic environment.

This process is far from safe! The dangers of milling with glass media are still not fully understood and further research is needed. Safety and fire protocol must be in place if one is even considering milling their own aluminium using glass. This would be inclusive, but not limited to, remote mill stop and start mechanisms, a safe and isolated milling location and fire prevention and control methods if an explosion of the mill jar was to occur.

Many individuals – some of whom are far from well-educated on the topic – have described the process of milling aluminium foil into dark aluminium powder so I will not go into excessive detail in this document. However, the general procedure involves using a blender to create small balls of aluminium foil which are then milled for upwards of three weeks with charcoal powder. The charcoal powder coats the aluminium as new surface area is exposed, preventing oxidation and resulting in a very fine non-oxidised powder of aluminium. This process must be done using very hard milling media for which $\frac{3}{4}$ " glass marbles often find use. If one plans to use such media, it is necessary to ensure the glass used has no colourants or patterns contained inside and is simply clear glass straight through. The additives used to colour the glass can often make it susceptible to sparking, which can lead to an explosion of the mill jar. Ultimately, although an effective method and one I personally use, undertaking this preparation can be very dangerous and much information left out of this document must also be considered. Further research is without a doubt needed before attempting this project.

Bicarbonate of Soda (NaHCO_3)

Bicarbonate of soda, also known as sodium bicarbonate, is a modifying agent and in rare occasions a colouring agent which produces a strong yellow hue. It is one of the easiest over the counter chemicals to find and it can be purchased at grocery stores for use as both a baking and cleaning product. Both grades will work equally well, however, with the far lower cost of the cleaning grade bicarbonate, it finds much more common use.

Note, if for some reason one is purchasing the food grade bicarbonate, 'Baking Powder' and 'Baking Soda' are different things. Baking soda is pure sodium bicarbonate but baking powder has numerous additives which reduce its effectiveness.

Potassium Chlorate (KClO_3)

Potassium chlorate finds extensive use in pyrotechnic colour compositions, especially those which are known for their vibrancy and colour purity even with relatively simple components. Although potassium chlorate cannot be purchased over the counter, it can be produced via a process known as electrolysis. This involves passing a current through an aqueous solution of potassium chloride (KCl) whereupon the water can be hydrolysed liberating H_2 from solution and oxidising the KCl into KClO , KClO_2 , and KClO_3 with the major product being formed as KClO_3 (Potassium Chlorate). The side products are then chemically destroyed and the chlorate is collected, processed and eventually dried and ground into a fine powder. This is a greatly oversimplified summarisation of the potassium chlorate production process and many internet articles do it much more justice than I am capable of. However, I can discuss the acquisition of the precursors to this chemical process as well as the acquisition of the electrodes required to produce potassium chlorate and other chlorates.

In researching potassium chlorate production, one will quickly find that certain types of electrodes are required to facilitate the addition of the desired three oxygen atoms to the chloride species. Simply using copper or steel electrodes, as is common in many electrochemical processes, will result only in the production of hypochlorite and chlorite species. To produce chlorate, the most common anodes used are MMO (Mixed Metal Oxide) and Graphite. Personally, I have never used graphite electrodes and cannot attest to their performance but my experiences with MMO anode Titanium cathode cells have been

successful enough I do not intend to ever experiment with graphite. Although I cannot give any specific direction as to where one may find OTC electrodes of this type – as I acquired mine from a dedicated supplier – I can say that the ‘Chlorination Units’ on home saltwater pools work by utilising a series of MMO anode Ti cathode plates alternatingly stacked and bolted together. Contacting a business that manufactures or supplies such things would be a good place to start.

The second problem one must face in producing potassium chlorate is acquiring potassium chloride - of which I have only managed to locate two sources. The first is in ‘Potassium Water Softening Tablets’ which are small chunks of KCl supplied in 20kg (40lb) bags for use in home water softening systems as an alternative to the supposedly less healthy sodium chloride. Although, after extensive searching, the conclusion I made was that – in Australia at least – sales of potassium chloride for this purpose are non-existent. As a result, I have never been able to experiment with this source of KCl. This is contrasted by the US where KCl water softener is often sold at grocery and hardware stores such as Costco and Home Depot. If you live in a nation where such a source is readily available, it would be my recommended sourcing as it does not require purification before use in electrolysis.

The second source I have managed to locate is ‘Muriate of Potash,’ an uncommon fertiliser with the NPK rating 0-0-50. Not to be confused with ‘Sulphate of Potash,’ a common hardware fertiliser, Muriate of Potash or MOP tends only to be sold in specialised agricultural stores such as those mentioned in the section above on potassium nitrate. Unlike potassium nitrate, MOP is not recognised as a potentially dangerous chemical and thus, the precautions undertaken when purchasing potassium nitrate are unnecessary. Simply calling up or checking on a supplier’s website will often list availability and pricing, which I have found to be approximately \$30 USD for a 25kg (50lb) bag.

A note to be made about the use of MOP as a source of KCl: unlike the water softening equivalent, fertiliser grade KCl almost always comes coated with a waxy red substance covering the crystals and locked within the crystal structure. Due to the insoluble nature of this coating, it can be removed by first dissolving the crystals in hot water, followed by filtering the solution. However, finding a filter that can trap the waxy coat can be a challenge. After many failures and upwards of 15kg of chloride wasted, the final solution I found is shown below. This filtration setup works to give a crystal-clear solution of KCl with only a single hot filtration, leaving a filtrate that can be added directly into an electrolysis cell.

Filter Paper Setup



Filtering Setup Side View



Filtering Setup Top View



As is evident in the images above, the setup used for filtering consists of a bucket onto which is attached a specialised filter paper. This filter paper is made by placing two, two sheet pieces of disposable kitchen towelling onto a piece of cloth, each offset by 90° to each other, followed by a third sheet placed 45° offset from the first two sheets (Image: Filter Paper Setup). On top of this, a second piece of cloth is placed to create a sandwich: cloth, paper towelling, cloth. In the image above, instead of a second sheet of cloth, the filter is made from one piece of cloth doubled over with the towelling sandwiched in the centre. When I first tested this and before purchasing a dedicated sheet of cloth, I used two old shirts with the paper towelling sandwiched in the centre which worked equally well. The main point of the cloth is only to stop the towelling from ripping. The cloth itself is not a particularly good filter and alone lets a large amount of the wax through. The proceeding two images show the filter as it is pegged to a bucket and ready to have liquid poured into it. The pegs hold the filter onto the bucket while the solution is passing through and allow easy removal when the process is complete.

The general procedure for this preparation is first to weigh 450g of chloride for every litre of cell volume you wish to fill. This measured KCl is then placed into a large pot and onto the KCl, the amount of water, respective of the volume of the cell, is added. This water is best boiled before the addition although this is not strictly necessary. The pot of water is then placed onto a burner or stove top and brought to a temperature high enough that all the KCl dissolves, leaving a bright red suspension. During this step, the solution must be heated well above the 40°C required to dissolve the chloride as the solution will cool very quickly once off heat and going through the filter. Once the solution has been brought to the desired temperature, it can be poured through the filter; this should yield a clear solution coming out the other side. This solution can then be added directly into an electrolysis cell to yield chlorate. Although there is no danger in this process, it is best done outside as the filtering can be messy.

Barium Chlorate ($\text{Ba}(\text{ClO}_3)_2$)

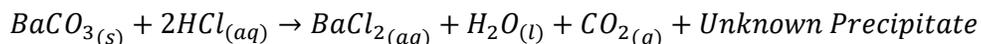
Barium chlorate is a strong oxidising agent used as a dual colouring and oxidising agent in both historical and modern-day compositions. Due to its high price, it is often combined with potassium chlorate to give vibrant green stars which are comparable even to those made with potassium perchlorate, a metallic fuel and a chlorine donor such as parlon or HCB. Like potassium chlorate, barium chlorate cannot be purchased directly, however, it can be synthesised via electrolysis of pottery store grade barium carbonate (BaCO_3).

The process of electrolysis to produce barium chlorate is identical to that used to produce potassium chlorate, thus, it will not be covered in this section. However, there are some key differences which are discussed in the synthesis below.

This preparation deals with toxic heavy metals in their soluble forms. The LD50 for soluble barium compounds is less than 20mg/kg. This means that for the average male, 1.5g of soluble barium is enough to kill! The information provided here is not sufficient to undertake this procedure safely. Before attempting this preparation, one must first research the further risks of this synthesis and put in place all relevant safety protocol.

The first step in preparing barium chlorate is to produce a solution of barium chloride which can undergo electrolysis. However, unlike potassium chloride, which has a number of domestic and agricultural uses, barium chloride has no such source and must be synthesised. To do this, one must first locate a source of barium and the most viable source for this is in pottery grade barium carbonate (BaCO_3) which is sold as an additive to ceramic glazes. Most ceramic supply stores will stock this as it is quite a common and benign chemical. Its price ranges from \$5-\$10 USD depending on the source and the quantity you purchase.

Once a source of barium carbonate has been acquired, the next stage of the preparation is reacting this carbonate with a strong chlorinating acid to displace the CO_3^{2-} species and substitute it with a Cl^- species. In laymen's terms, we must neutralise the BaCO_3 with HCl, yielding a solution of soluble BaCl_2 and liberating CO_2 gas. Below this reaction is shown.



Notice the presence of an 'Unknown Precipitate' in the equation. Although in ideal conditions the BaCO_3 would react completely to yield a clear solution of chloride, in reality, this is not the case. The results of your experimentation may vary, although, in my personal experience, after adding a stoichiometric volume of concentrated 31.45% (10M) HCl, a white powder remained in suspension and as a sludge at the bottom of the reaction vessel. Further, even after the addition of more HCl and water to this sludge, no reaction was observed, implying both very low solubility in water and non-reactivity with HCl. After further testing, I came to no conclusion as to what this material was, although, upon drying and weighing, it was determined that this powder constituted approximately 10% of the initial barium carbonate sample.

The electrolysis process, which is to be performed in latter steps of this production, requires a solution of reasonable purity. Thus, the next stage of this preparation is removing this thick insoluble sludge from the BaCl_2 solution. To achieve this, I have attempted many different techniques, however, after extensive testing, the method which I determined to be most effective was filtration. To undertake this separation, the solution is passed once through the filter setup I designed for purifying agricultural grade potassium chloride. This setup is described in the above section on potassium chlorate and shall thus not be restated here. Refer to this section for the methodology behind setting up this filtering apparatus.

Irrespective of the method one uses to remove the sludge – which may in fact not even be present depending on the quality of your carbonate source – the next stage in barium chlorate manufacture is electrolysis of this barium chloride solution. If the volume of solution remaining after this neutralisation reaction exceeds the volume of your cell, the solution may be left out in the sun for a number of days to remove excess water. However, this should generally not be an issue. In fact, it is more likely the solution will need to be diluted to reach the desired volume. Regardless, once the desired volume is reached, the solution is set up for electrolysis. This process generally takes between seven and ten days to yield a solution of barium chlorate, although, these numbers are drawn only from my personal experiences.

Note here that there are some key differences between the electrolysis of barium and potassium chlorate, which I have observed that the reader may be helped having known. Firstly, unlike potassium chlorate electrolysis, the electrolysis of this pottery grade barium chlorate often quickly turns a deep grey colour and precipitates small white flakes on the bottom of the cell. This is nothing to be alarmed by; the

reaction is still proceeding. My understanding is that this colour change is due to side reactions occurring in solution because of impurities in the carbonate source. Images of this discolouration are shown below.

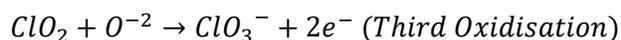
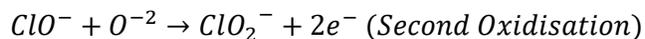
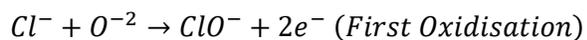
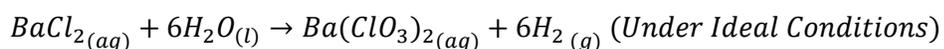
Electrolysis of Barium Chlorate on Approximately Day Ten



Secondly, unlike the electrolysis of potassium chlorate, which yields an evident crop of crystals at the bottom of the cell, the solubility of barium chlorate is so high – higher than barium chloride in fact – that once formed, the barium chlorate remains in solution. This is not an immediate issue and is dealt with in subsequent steps, however, it does make it quite difficult to determine the end point of the electrolysis. This is an important point to be able to identify as a large reduction in the concentration of reactants can lead to damage and premature failure of the MMO anode. Although, as of yet, without a hydrometer available, I am forced to simply guess when the process is complete and accept the damage to my anode which does occur.

Other than these two distinctions, the electrolysis of barium chlorate is identical to that of potassium chlorate, i.e., the electrodes, electrode spacing, cell type and power supply can all be identical. In fact, I use the same cell for both potassium and barium electrolysis with no issues.

Reaction Mechanism



Under ideal conditions, the chloride ion is oxidised three times to produce the final chlorate ion, passing through the hypochlorite and chlorite intermediates. However, in reality, the electrolysis produces a mixture of all three of these species, in varying proportions, in accordance with the conditions in which the electrolysis takes place. This is more so the theory of electrolysis than the practical side of things and I

will not go into excessive detail about the chemistry here. Although, needless to say, after the completion of the electrolysis, these species must be destroyed for safety reasons. Note the barium spectator ion is emitted from these half reactions.

After the electrolysis has reached completion, or a judgment call is made, the solution exists as a suspension of black particles. Once power is removed, the electrodes and lid are taken off the main cell and the lid is replaced with a piece of saran wrap or another appropriate cover to prevent dust from entering the electrolyte. This solution is then sat on a bench overnight to cool to room temperature and allow the floating particulate to settle to the bottom of the cell. This leaves a crystal-clear solution on top with a dark brown precipitate settled at the bottom. Once this separation is observed, the supernatant can be decanted off into a separate container being careful not to allow any of the sediment into this first pour. This should leave at most a few hundred millilitres at the bottom of the cell which contains the black particulate. This can either be discarded and counted as loss or passed through a coffee filter to yield a solution that can be added to the supernatant.

After completing these steps, a clear solution of barium chlorate, along with the various intermediate products is produced, however, unlike when producing potassium chlorate which is now precipitated by cooling the solution, the solubility of barium chlorate is so high – even at 0°C – the only viable method for its recovery is the evaporation of the water it is solvated in. This is achieved most simply by placing the solution in a wide mouth bucket for several weeks outside until the water is evaporatively removed. For the impatient among us – me included – a method to increase the rate of this process is to use a small desktop fan which can be purchased at many department and cheap stores. Secured over the lip of the bucket and aimed at the liquid, this can cut the drying process time in half. An image of this setup is provided below. Note that the insect net attached to the top of the bucket is to prevent unsuspecting insects from entering and getting caught in the solution, contaminating the final product.

Evaporation Bucket with Net



Evaporation Bucket with Net



Evaporation Bucket no Net



After one to two weeks have passed, this evaporation method is able to remove almost all the water from the large 5L batches of electrolyte I generally run. From here, the remaining water can either be removed by continuing this process in the evaporation bucket or by removing what remains and placing it on trays in the sun. However, both of these processes leave the final barium chlorate with a slight yellow tint as opposed to the pure white one would expect. To fix this, I have found that placing the almost dry chlorate from the evaporating bucket onto metal trays and roasting it for about 30 minutes at 100°C (212°F) removes this yellow hue and leaves the powder a pure bright white. It is necessary to purchase a small

toaster oven for this purpose, which can often be found on local classifieds, as barium chlorate is much too toxic to place in an oven intended for food.

I have, as of yet, not found an explanation for why this process turns the crystals white. Someone once proposed the barium chlorate at high temperature was oxidising the contamination into some other form, although, I find this unlikely. Another proposal was that the heat was liberating the barium chlorate's waters of crystallisation changing its colour, however, I doubt this as the colour change never reverts. In any case, it is a nice aesthetic touch.

Whatever the process, once this final drying has been completed, the powder can be left to cool then crushed or milled and placed in storage - and it does indeed work very well for its intended purpose. To the right is an image of barium chlorate produced via this preparation, mixed in an 80:20 ratio with shellac burning in a small crucible. Even from very close up when colour compositions can look washed out, the barium chlorate clearly gives a very pure green colour with a large flame envelope and nice band of emission. Though the process to produce this barium chlorate is long and quite involved, the quality of green achievable is well worth the time.

Barium Chlorate Shellac 80:20



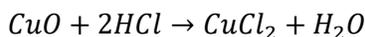
Copper Oxychloride ($\text{Cu}_2(\text{OH})_3\text{Cl}$)

Copper Oxychloride is an uncommon compound of copper which finds some use as a fungicide in agriculture. However, testing has shown this to be an inappropriate source for pyrotechnics. The main use of copper oxychloride in pyrotechnics is as a colouring agent in blue and purple stars as well as a catalyst in various exotic rocket fuels.

Production of copper oxychloride can be achieved by a number of syntheses; the method which I cover here is simply the one I use and many others exist. One of the most popular alternative methods is the electrolysis of copper metal to cuprous oxide (Cu_2O) followed by chlorination and then oxidation with atmospheric oxygen. Many procedures for this type of synthesis are available so I will not go into excessive detail here.

The method I employ for producing copper oxychloride is first reacting Cupric Oxide (CuO) with HCl then adding potassium hydroxide to precipitate copper oxychloride. An alternate method which I have employed in the past is the substitution of KOH with Potassium Carbonate (K_2CO_3) which yields oxychloride via a slightly different pathway. Both are discussed here, although, I will preface this synthesis by saying I prefer the KOH method due to the speed at which it can be conducted. The K_2CO_3 method takes much longer due to the foaming that occurs as a result of liberated CO_2 and the time it takes for this to subside.

The first step in producing copper oxychloride is preparing a solution of CuCl_2 which I personally do by adding a stoichiometric quantity of 10M 31.45% HCl – from the hardware store – to about 200g of cupric oxide (Black Copper Oxide). Black copper oxide is sold at almost all pottery stores as a colourant for ceramics, ranging from \$10-\$50 USD per kilogram. Below is shown the chemical equation for this reaction.

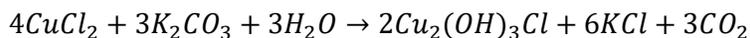
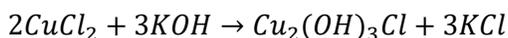


Once this HCl has been added, a dark green solution of solvated copper chloride is produced as a complex in the form $[\text{CuCl}_4]^{-2}$ along with solvated $[\text{Cu}]^{+2}$



An alternate procedure to attain a solution of copper chloride is first reacting copper sulfate pentahydrate – sold as a fungicide in just about every hardware store – with a stoichiometric amount of potassium carbonate to yield copper carbonate. This copper carbonate can then be reacted with HCl, liberating CO_2 and yielding a solution of copper chloride. Further information on this alternate pathway is available in various books and online.

Once a solution of copper chloride has been attained, the next stage in the preparation is to convert it to copper oxychloride by the addition of either KOH or K_2CO_3 . Both pathways are written out below.



KOH is sold at most good soap supply stores for use in producing liquid soaps through saponification. It generally costs between \$5-\$10 USD per kilogram. K_2CO_3 can be found at most pottery supply stores under either the name ‘Potash,’ or more commonly ‘Pearl Ash,’ for use as a flux in ceramics. The price of K_2CO_3 from this source is generally around \$5 USD per kilogram.

A note for producing oxychloride via the KOH method: the addition of the KOH to the solution must not be done too fast or at too high or low a temperature. These conditions are capable of leading to the production of the undesired side products, CuO and CuCl_2 , which can contaminate the product. In the case of CuO, it can be preferentially produced over the oxychloride, meaning no oxychloride is produced at all. Further, although stoichiometrically, one mole of KOH is required per mole of CuCl_2 , slightly basic conditions are required for maximum yield, thus, a slight excess of KOH is always required. No such problems exist with the K_2CO_3 method.



Regardless of the method used to convert the CuCl_2 into copper oxychloride, the final stage of the preparation is separating the oxychloride from suspension. This is done by allowing the suspension to stand, upon which the insoluble copper oxychloride settles to the bottom of the reaction vessel. The KCl supernatant is then decanted off into a separate vessel and the oxychloride is rinsed onto a filtering setup with distilled water. Once in a funnel, it can be rinsed with distilled water and left out on a watch glass or in a cool oven to dry. It can then be broken up and stored for later use.

Polyvinyl chloride (PVC) (C₂H₃Cl)_n

PVC, or polyvinyl chloride, is a complex polymer chain of the vinyl chloride monomer, which is used primarily as a chlorine donor in pyrotechnic compositions, especially those which contain potassium chlorate as their primary oxidising agent. Without a doubt, PVC is the most difficult chemical on this list to find and acquiring it stretches the premise of OTC.

Many companies specialise in the production of onsite PVC injection moulded parts for high-speed prototyping. These companies only generally work with what are called 'PVC Blends,' which are a combination of pure PVC powder along with plasticising agents, colourants and fillers. However, the companies that supply them these 'blends' have access to pure PVC powder, known in industry as 'PVC Dry Blend.'

A google search for "PVC Resin Manufactures [City]," "PVC Dry Blend [City]" or "PVC Resin Suppliers [City]" will likely find relevant results. In most cases, if you call and inform them you would be willing to come and pick up the bag, they will be more than happy to sell one to you. It is important to know your terminology, so do a bit of reading on the Wikipedia page for PVC as well as some industry websites. The main information you will need to provide is that you are looking for PVC Dry Blend with no plasticisers or additives.

A few other important distinctions you may come across: they may ask if you are after 'Rigid' or 'Flexible' PVC dry blend. The flexible PVC has plasticisers so purchase the rigid type. They may also ask if you want 'Emulsion Grade' or 'Suspension Grade' PVC, chemically, these two products are identical, however, they are not the same. The physical conditions in the reaction vessel which produced the polymers were different and thus produce differently sized particles of PVC. Emulsion grade PVC is the finer of the two powders and thus, is desired if available. However, I have never been personally able to find it and just mill the suspension grade PVC down to a fine powder.

Depending on who you know, the cost of a 25kg (50lb) bag of PVC can vary wildly. However, in my personal experience, a bag costs around \$120 USD. Although, I know others who have been able to acquire a bag for free simply because they knew someone in the industry.

PVC Dry Blend Bag



Suspension Grade PVC Powder



Red Gum

Red gum, especially in recent decades, has found ever increasing use in pyrotechnic compositions, valued for its relatively low cost and spectacular performance in perchlorate and chlorate pyrotechnic compositions. Unfortunately, unlike the other chemicals on this list, red gum is a chemical exclusively available to Australian pyrotechnicians because it is neither purchased or produced; it is harvested.

Note here that for those not fortunate enough to live in Australia, Red Gum can be substituted in many compositions for shellac whose sourcing is discussed in the section below.

Red gum is a resin secreted by the 'Xanthorrhoea' family of plants, which grow exclusively on the Australian sub-continent. As they age, or when exposed to flame, the plant seeps the resin from its trunk where it collects as small deep red nodules of gum. These nodules can be removed from the tree itself or from the ground surrounding the tree where they occasionally fall. These nodules are then ground directly into a fine powder, which is at least as pure if not purer than the product produced industrially by grinding the plant to extract its resin.

The images below do not belong to me and are taken from a post by "Twignberry" on the APC under the topic "Harvesting Red Gum (Australians Only :P)"

Xanthorrhoea Plants



Resin Nodules



Broken Xanthorrhoea



Shellac

Shellac is a golden yellow to red powder, secreted by the lac bug and collected by hand. In the past, it was utilised extensively as a wood finish and additive in varnishes, however, due to its high price, it has fallen out of favour in recent years. In pyrotechnics, shellac is used as a pure burning, low-temperature fuel and occasionally as a very weak, often secondary, binding agent.

Compared to fifty years ago, shellac has become much more elusive but most major hardware stores still stock shellac flakes, located in the painting section. If the local hardware store turns up nothing, try a dedicated art store where shellac is often sold to individuals wanting to mix varnishes. If neither of these stores stock shellac, try searching the internet for a dedicated hobby painting store which will almost always stock shellac or be able to give you directions as to where to locate it.

Strontium Carbonate (SrCO_3)

Strontium carbonate is a seldom utilised red colouring agent in pyrotechnic compositions, most often those containing potassium chlorate. The more common form of strontium in pyrotechnics is strontium nitrate, however, there is no over the counter source of this I am aware of.

Strontium carbonate can be found in most large pottery stores as a replacement for barium carbonate in pottery glazes. A white powder in appearance, it generally costs \$30-\$100 USD per kilogram depending on the source and quantity purchased.

Calcium Carbonate (CaCO_3)

Calcium carbonate is a very seldom utilised orange colouring agent in pyrotechnic compositions, a modifying agent for some glitter compositions and reagent in some pyrotechnic chemical syntheses.

Calcium carbonate can be found at almost all pottery stores for \$2-\$4 USD per kilogram. Alternatively, calcium carbonate powder can be produced by grinding eggshells into a fine powder. Many more OTC sources are available in the form of various products.

Red Iron Oxide (Fe_2O_3)

Red iron oxide is used as an additive to various prime compositions and also as a component in some star compositions, giving a very bright orange to red flame. Of course, iron oxide also finds use in the famous – maybe even infamous – thermite reaction.

Sources of iron oxide are numerous, however, the best source of iron oxide is pottery supply stores where it is sold for use in colouring of pottery. Pottery suppliers generally stock iron oxide in 1kg bags ranging from \$3-\$5 USD. An alternate source of Fe_2O_3 is the concrete section of the local hardware store where it can be found as an additive to turn concrete bright red. A number of syntheses for producing iron oxide also exist, although, compared to its purchase, these are almost always not economical, so I will not go into them here.