AN INTRODUCTION TO FIREWORK CHEMISTRY

All fireworks are 'explosive' materials; they contain chemical compounds and substances which, when ignited, produce energy in the form of heat, light and sound. These qualities enable fireworks to entertain visually with both colour and movement.

Although fireworks are classed as explosives, they are not 'high explosives' (which would refer to dynamite, for example). Fireworks produce combustion energy in a relatively slow and controlled way – think about 'fountains' or 'catherine wheels' which burn at quite a gentle pace. Other types of fireworks burn very quickly; 'star shells' – which produce the large chrysanthemum bursts in the sky, do seem to explode and their energy is released rapidly. The performance of the different types of fireworks depends on the underlying chemistry and how they are manufactured.

A 'fountain' type firework

Spectacular aerial shells

Blackpowder

The main ingredient of fireworks is gunpowder (often called 'blackpowder'), which has been used in various forms for centuries! A very crude version was developed by the Chinese as early as 1,000 AD although the scholar and Monk Roger Bacon refined our understanding of blackpowder between 1235 and 1290AD.

The basic constituents of blackpowder are *potassium nitrate* (saltpetre), *charcoal* and *sulphur.* However, it is not just a simple loose mixture; in fact, such a mixture is very difficult to light. The ingredients need to brought into very lose physical contact and this is achieved by 'milling' and high-pressure pressing process. This produces a gunpowder 'cake' which is then broken up. The final product is 'granular' gunpowder and it is subsequently graded according to its grain size, by passing through a sieving process.

When blackpowder is lit, the components react together in a very complicated way and no one is quite sure of the precise 'chemistry' going on. The reaction products are numerous and it is almost impossible to write a balanced chemical equation for the process. However, gunpowder produces energy very rapidly and many of the by -products are gases, which is very important in firework design and manufacture. The rapid evolution of gas can be used to provide a thrust force in rockets or to lift a shell out of its mortar tube.

When blackpowder is used in firework manufacture, the gain size is very important. As mentioned in the introduction, sometimes we want slow burning and other times a rapid effect – this depends on the grain size or how well compressed the gunpowder is. In rocket motors, for example, the powder is very highly compressed so that it is, in effect, a solid. The burning of the solid gunpowder block in rocket motors is quite steady (to produce an even 'thrust'). On the other hand, gunpowder in traditional 'bangers' is very loose and it burns quickly.

Sparks and Colour

A fountain produces a jet of sparks, and while its basic constituent is blackpowder, the sparks are produced by additional substances called *emitters*. These emitters may (for example) be fine iron-filings which, when ignited, burn to produce golden sparks. The iron is *oxidised* by means of a reaction with the air and produces its characteristic colour as a result of some rather complex behaviour at an atomic level. What we perceive as 'colour' is very much related to the behaviour of atoms when they are given energy in some way. Aluminium and titanium metals, in a 'particle' form, are also used in fountains to give a silver or 'flitter' type effect. Often, the metal particles need to be coated in some way to protect them from deterioration over a long period in the body of the firework. Certain fountains do not store well because the metal powders naturally oxidise in the air while the fireworks are 'on the shelf'.

Colours are produced by introducing a variety of chemical compounds. The familiar 'flame tests' undertaken in chemistry lessons at school remind us that certain chemicals (usually in the form of a metal 'salt') produce characteristic colours. Typical examples are *barium* salts, which produce a green colour and *strontium* salts, which generate red.

A brilliant green 'star' from a roman candle may, for example, contain the following ingredients

Barium Chlorate	72%	(this is the 'colour agent')
Barium Carbonate	4%	
Charcoal	8%	
Acaroid Resin	12%	
Dextrin	4%	(a type of starch - acts as a 'binder')

Again, the process by which the colour is produced is a very complex one and chlorine is often very important in the chemical process. In the overall reaction, a 'colour species' must be generated and in the above case it is *barium chloride* BaCl, which appears as a result of the star burning process.

In recent years, there has been considerable improvement in the quality of firework colour production. Colours such as violet and orange have been traditionally difficult to generate but, with modern chemical techniques, these hurdles have been overcome and spectators are now able to enjoy a far better visual experience than ever before.

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Important Ingredients

Generally speaking, the various chemicals used in firework manufacture can be sub-divided into the following categories

Oxidising Agents	(eg Potassium Nitrate) *provide essential oxygen*
Fuels	(eg charcoal)
Colour Agents	*essential to produce specific colours*
Binding Agents	(eg dextrin) *act as a 'glue' to hold chemicals together*
Stabilisers	*which help to prevent unwanted reactions*
Enhancers	*certain chemicals which could, for example, deepen a colour*
De-sensitisers	*assist in reducing the sensitivity of certain mixtures*

It is important to realise that many chemicals are unstable and highly reactive; hence firework chemistry requires considerable understanding and experience to 'get it right'. Indeed, many firework recipies are closely guarded secrets having been obtained through many years of refinement.

This short article is intended simply to provide a brief introduction to the chemistry of fireworks. The following books are recommended to those readers interested in pursuing this extensive subject in greater depth

Fireworks Principles and Practice (3rd Edn)
Rev R Lancaster MBE
Chemical Publishing Company (New York) 1998

The Chemistry of Fireworks
Michael S Russell
RSC Paperbacks 2000

Pyrotechnics
Alexander P Hardt
Pyrotechnia Publications 2001

Chemistry of Powder and Explosives
T L Davies
John Wiley and Sons (New York) 1943