The Colour of Fireworks!

Firework displays are used to celebrate many different occasions, and are used by cultures all over the world. These days the shows feature an impressive arrangement of sights and sounds, and the magical colours captivate audiences of all ages. Have you ever wondered how they work? It may not come as much of a surprise to hear that the answer to this exciting phenomenon lies somewhere in Science!

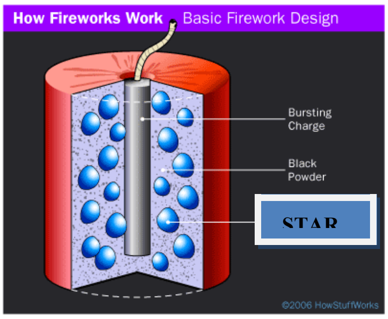

Image taken from 'howstuffworks.com'

This diagram shows the basic structure of a firework. The key components that determine the colours we see are packed inside the **stars**. These pellets contain metal salts, or other compounds, that emit different colours when ignited.

IMPORTANT! A Firework is a type of <u>explosive</u>, and therefore extremely dangerous. You must NEVER handle them without the supervision of an adult.

Before the 19th century, pyrotechnicians (the people who work with fireworks) were limited to using steel and charcoal to give yellow and orange colours in the sky. However, recent developments in chemistry have given the impressive spectrum of colours we see today. There are two main mechanisms of colour production in fireworks: **<u>Incandescence</u>** and **<u>Luminescence.</u>**

<u>Incandescence</u>

This is the emission of visible light due to heat. The hot components in a firework radiate heat energy in the form of electromagnetic radiation.

*Quick recap…*Electromagnetic radiation is energy that travels in the form of a wave. Different radiation energies correspond to waves with different wavelengths, forming a continuous spectrum. Visible light is one type of electromagnetic radiation with wavelength within a particular range of this spectrum.

The glow components of a firework, such the charcoal, can be compared to a theoretical object called a blackbody. This is something that radiates energy at every wavelength, and although not a perfect match, the comparison turns out to be quite reasonable! The following diagram shows the radiation emitted from three blackbodies at different temperatures (given in Kelvin):

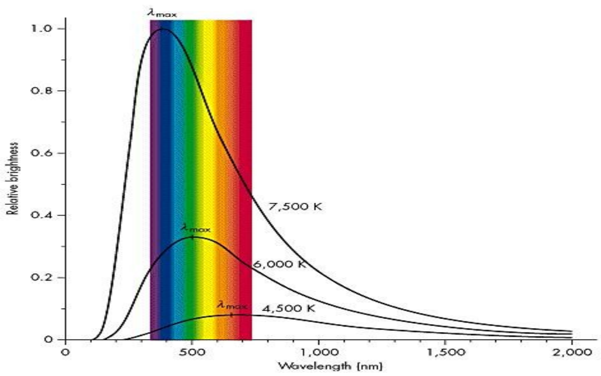

Image taken from 'www.astro.washington.edu'

The peaks of these curves represent the wavelength at which most of the radiation is emitted. From this we see that the temperature of a blackbody determines the wavelength of the peak emission, and hence the colour of the light we see.

Pyrotechnicians can control the temperature of their fireworks, and therefore have the power to manipulate the colours we see. However, it can be seen from the diagram that colours near blue and purple end of the visible spectrum require blackbodies at the highest temperatures. Some of these temperatures are impractical for fireworks, and so this method is limited to reds, oranges and yellows.

Luminescence

This is a mechanism which can occur at much lower temperatures, and the light it produces comes from movements within the structure of atoms.

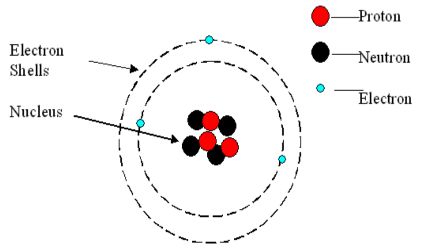

Image taken from 'www.sciencepages.co.uk'

Quick recap… Atomic Structure!
Inside every atom sits a heavy nucleus of protons and neutrons. Electrons orbit in a series of shells or energy levels, at an increasing distance from the nucleus. It is important to remember that each energy level can only hold a certain number of electrons, and they must have the correct energy for the particular shell.

It follows that if an electron absorbs energy, it is forced to move to a higher level to match the new the energy it has, and the atom is considered to be in an excited state. This re-arrangement is not stable enough to last very long, and the electron quickly falls back to its original level. We know that the extra energy the electron loses can't just disappear! Thankfully scientists have discovered that this energy is given out as a photon, which is the particle that carries energy in electromagnetic radiation, and is therefore the particle that makes up visible light!

Pyrotechnicians were smart, and they used this development in science to help them with the colours of their fireworks. They found that since each transition would depend on the structure of the molecule, there would be certain compounds that emitted photons with energy (and corresponding wavelength) in the visible region of the electromagnetic spectrum.

Much work has gone into finding stable compounds that produce specific colours, and can also be safely packed into fireworks! The table shows the main discoveries to date:

Colour	Compound
Red	strontium salts ($SrCO_3$), lithium salts (Li_2CO_3)
Orange	Calcium salts ($CaCl_2$)
Gold	Incandescence of iron (with carbon), charcoal, or lampblack
Yellow	sodium compounds ($NaNO_3$)
Electric White	white-hot metal, such as barium oxide BaO
Green	barium compounds + chlorine producer ($BaCl^+$)
Blue	copper compounds + chlorine producer $Cu_3As_2O_3Cu(C_2H_3O_2)_2$
Purple	mixture of strontium (red) and copper (blue) compounds
Silver	burning aluminium, titanium, or magnesium powder or flakes

Table based on information given by 'www.about.com:chemistry'

Pyrotechnicians continue to search for new and exciting colours to use in fireworks. Although developed compounds have improved the intensity of the colours in their displays, nobody has been able to produce ocean or forest green, and such quests keep the development of fireworks very exciting!

Interested to learn more about the colours of Fireworks?

A-Level Chemistry develops these topics, and will give you a better understanding of the concepts. In the meantime, try the following web pages for more information:

http://www.open2.net/roughscience2/html/challenges/fireworks/fireworks_03.htm (easy to understand)
http://www.gcsescience.com/rc10-fireworks.htm (easy to understand)
http://scifun.chem.wisc.edu/CHEMWEEK/fireworks/fireworks.htm (more advanced science)

References

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