Use of s-Block Compounds in Fireworks

Fireworks displayed over the Victoria Harbour

What are fireworks?

Have you ever been to an aerial firework show at the Victoria Harbour? Do you know what gives them spectacular colours or effects? The term " fireworks " is usually used to describe an explosive that gives off incandescent light or luminescence in an aerial display. Sometimes it refers to gun-powder which is made by mixing equal amounts of sulphur, charcoal and potassium nitrate(V). The mixture can be easily ignited with a single spark.

What are fireworks made of?

Fireworks are usually made of the following substances: an oxidising agent, a reducing agent, a colouring agent, binders and regulators. When mixed together, they form the basic ingredients of fireworks.

Oxidizer agents

The oxidising agents produce the oxygen required for burning the mixture. Typical oxidising agents used in fireworks are nitrates, chlorates or perchlorates. The most common oxidising agents used are nitrates. However, nitrates usually only give up a third of their oxygen, and therefore are not suitable if we want to create a firework with striking effect. Another type of oxidising agent is chlorates (*e.g.* $KClO_3$). Chlorates give up all of their oxygen, causing a more spectacular reaction. However, it is more dangerous to use as it makes the chemicals extremely explosive. Therefore, perchlorates (*e.g.* $KClO_4$) which contain more oxygen but are less explosive than chlorates are often preferred.

Reducing agents

The second component of fireworks is the reducing agents. The reducing agents consumes the oxygen produced by the oxidising agents to produce hot gases. Two typical examples of reducing agents are sulphur and charcoal (carbon). They react with the oxygen to form sulphur dioxide and carbon dioxide respectively. Usually two reducing agents are combined and result in speeding or slowing of the reaction. Therefore, the reducing agents are important in controlling the speed of the reaction. Besides, metals are often added to speed up the reaction. The finer the metal powder used, the faster the reaction will be.

Binders and coloring agents

The binders in a firework are the components that hold the mixture together in the form of lump. This lump is normally referred to as a star. In order to form a star, two main elements are used. These are dextrine dampened by water, or a shellac compound dampened by alcohol. The coloring agents are used to give off the emitted colors that are required in the fireworks. The colors produced depend on the chemicals used.

Why do we use s-block compounds?

S-block elements refer to the elements in Groups I and II of the Periodic Table. We use s-block compounds in fireworks because of their unique explosive properties and their ability to act as emitters of visible light. Light emitters can be grouped into two main categories: solid-state emitters (black body radiation) and gas phase emitters (molecules and atoms). A black body is an ideal emitter as it absorbs and emits all frequencies of radiation uniformly. Examples include steel and charcoal, which produce various yellow and orange colours. However with grey-body emitters it is not possible to produce anything but shades of orange and yellow. That is why gas phase emitters are used instead. In theory, blue light could be generated with a hypothetical black or grey body at temperatures over 9,000 K, which is the temperature of blue stars. However such temperatures are not appropriate or reproducible for fireworks. So for other colours, we need specific emitters of visible light. These emitters come from compounds of s-block elements.

Characteristic flame colours of some s-block elements

Metal ion	**Colour**
Lithium	Deep red
Sodium	Golden yellow
Potassium	Lilac
Rubidium	Red
Caesium	Blue
Calcium	Brick red
Strontium	Blood red
Barium	Apple green

Although there is a wide range of atomic and especially molecular emissions available from compounds, yet there are surprisingly few suitable emitters due to several factors. Firstly, some elements can emit so strongly that when mixed with another element, it can overshadow the emission and change the required color causing the color to shift into another region. A good example is that a composite blue and green color is expected to be made of barium(I) chloride (BaCl) and copper(I) chloride (CuCl) emissions. However, BaCl emission is seldom free from interference of BaOH and BaO emissions, which falls in the yellow and yellowish-green region of the visible spectrum making bluish green colors hard to obtain in fireworks.

Another problem is the high reactivity of some elements, which are used in making the corresponding emitters. Emitters *e.g.* strontium(I) chloride (SrCl) and BaCl, are so reactive that they cannot be packed directly into a firework. To generate these emitters, special methods have been designed to produce the emitters and allow them to evaporate into the flames at high temperature in order to maximize the output of light. In order to get good colours, there must be substantial amounts of emitters present in the flame with a good oxidising system to produce the high temperature required. Powdered magnesium and aluminium are sometimes added to fireworks for their ability to raise the flame temperature and also to increase the brightness.

Are there different types of fireworks?

Each type of firework has been designed to create the desired effect which is especially important in aerial firework displays.

Sparklers

A sparkler consists of all the substances that are found in any firework. The chemicals are mixed to form a slurry, which is then coated onto a wire. Once dried it then forms the sparkler which will burn from one end to the other when ignited. The fuel and oxidising agent used are proportioned, along with the other chemicals, so that the sparkler burns slowly rather than explodes

instantaneously. Sometimes aluminium or magnesium dust is added in the firework so that bright and shimmering sparks are created.

Aerial fireworks

An aerial firework is normally constructed as a shell that consists of four parts:

- Container
- Stars – Spheres
- Bursting charge
- Fuse - Provides a time delay so the shell explodes at the right altitude

Aerial shells contain all the chemicals that, when ignited, produce the brilliant flash of colored light. These shells are loaded as small cannons. When the cannons are fired into the sky, the shells fuse burns whilst rising to its correct altitude. Once the shell reaches the required altitude, the fuse ignites the bursting charge and causing it to explode. The explosion ignites the outside of the stars. Then the stars begin to burn with bright showers of sparks. Since the explosion throws the stars in all directions, a huge sphere of sparkling light is observed. This is most common to be observed in firework displays. The pattern displayed in the sky depends on the arrangement of star pellets inside the shell.

Questions

1. What are the major components of fireworks? What are their functions?

2. Why are perchlorates more commonly used than chlorates and nitrates in making fireworks? Explain your answers using chemical equations.

3. Explain why it is preferable to use s-block compounds rather than d-block compounds in fireworks.

4. Give a list of various colours of fireworks and the corresponding compounds used.

5. Explain why magnesium powder or aluminium powder is usually added in fireworks.

References

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