THE CHEMISTRY OF FIREWORKS

(1) Fireworks have lit up the night sky and dazzled and delighted audiences for years since they were first invented in China between the 9th and 11th century. Though many of us have seen fireworks before, we have no idea what they are made of and how they work. Any aerial firework (one launched into the sky before exploding) needs to have the following components: 1) a tubular container that holds all the firework chemicals together, 2) an explosive propellant which shoots the firework into the sky like a missile 3) chemicals which will glow with different colors in the sky 4) a secondary explosive which will scatter the glowing colored chemicals and 5) a fuse, which when lit, will provide the spark needed to ignite the explosive materials.

(2) To propel a firework into the air, a big explosive charge must be released and aimed towards the ground. This is not the blast that causes the firework to go off, it merely launches the firework into the air and away from the spectators on the ground. The propelling blast is caused by igniting a substance called black powder (also known as gun powder) which was also invented by the Chinese in the 9th Century.

(3) Traditionally, black powder is made up of 75% potassium nitrate, 15% charcoal and 10% sulfur (though modern mixtures might omit the sulfur, increase the potassium nitrate and contain other chemicals). The charcoal and sulfur act as the fuel (the material to be burned) and the potassium nitrate is the oxidizing agent (which provides a supply of oxygen to the reaction to promote and maintain combustion). A fuse is attached to the black powder at the base of the firework. The role of the fuse is to delay ignition. The fuse is long enough so that there is time for someone to run to safety once the fuse has been lit. After a few seconds, the burning fuse will reach the black powder and the powder will combust which will blast the firework into the sky. Large fireworks can launch up to 1200 ft (366 meters) before exploding and reach a velocity of over 330 miles/hour (531 km/hour) while ascending. The larger the firework, the more black power it will contain and the higher and faster it will go.

(4) Once in the sky, the firework needs to explode. This will require a second explosion and more black powder. This powder is timed to explode only after the firework reaches its intended height. This is accomplished by a secondary fuse which begins burning when the firework blasts off the ground. The length of the secondary fuse corresponds with the length of the time delay required for the firework to reach it full height. Within the black powder is embedded pellets of chemicals which will produce the spectacular light and colors of the firework when they explode. These pellets are called “stars”. When the black powder explodes, it simultaneously ignites the stars as well as sends them flying outward with the force of the explosion. The color and pattern produced by the firework depends on the chemicals found in the stars and how the stars are arranged and packed within the black powder.

(5) The stars are made from metal powders and metal salts. A metal salt is a compound made from a metal and one or more non-metals ionically bonded together (e.g. copper carbonate, $CuCO_3$). You might have seen a demonstration of metals being burned in a flame test at school. During a flame test the metal is heated (usually with a Bunsen burner) in the flame and the metal will glow with a very intense color. Different metals will have different colors. For example, barium will glow green, so barium nitrate, $Ba(NO_3)_2$, in stars will produce green fireworks. Calcium will glow orange so calcium carbonate, $CaCO_3$, is a good choice for an orange colored firework. Strontium nitrate, $Sr(NO_3)_2$, is a great option

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for red fireworks since strontium will glow red when burned. Pure magnesium powder, Mg, is used in stars to create an intense white light.

(6) When metals are heated, the electrons of the metal atoms go from their lowest energy ground state to a higher energy level called the excited state. They do this by absorbing the energy of the heat around them produced by the exploding firework. However, the excited state is an unstable one so the electrons soon drop down to their ground state again. To do so they must get rid of the excess energy they absorbed. The electrons do this by emitting light energy which we see as the burst of light from the firework. Since each type of metal atom is different, the color produced by their electrons moving from the excited state to the ground state also varies.

(7) Not all fireworks are made equal. One way to tell the difference between cheap and good quality fireworks is to observe blue fireworks. Blue is a difficult color to produce because blue is produced by burning copper salts and copper compounds are usually unstable at high temperatures. They normally don't hold up well at the temperatures found in firework explosions. Only better made fireworks with better materials and quality construction will be able to produce a deep and convincing blue color.

Article Questions

1) What are the components of black powder and why are they needed to cause an explosion?

2) Why does an aerial firework require two explosions of black powder?

3) What would happen if the secondary fuse in the aerial firework was made too short?

4) What are "stars"?

5) What metals and metal salts would produce the following colors when burned?

a) orange _____ c) white _____
b) blue _____ d) green _____

6) What causes the stars to give off light when ignited?

7) In poor quality fireworks, what will you notice and why?