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The Science of Fireworks

Do you enjoy your town's annual fireworks display for the Fourth of July? The colors in a fireworks display depend on the wavelengths of light emitted by different chemicals as they burn. Light with the shortest wavelength appears violet in color. Light with the longest wavelength appears red.

More than one thousand years ago, Chinese people made black powder, the original gunpowder used in pyrotechnics. The word "pyrotechnics" comes from the Greek words for "fire art." Explosive and dazzling, a fireworks display is both a science and an art. The Chinese used the powder to set off firecrackers and small missiles. Black powder is still used today to launch fireworks into the air and to give fireworks an explosive charge. Even the ingredients, mainly saltpeter (potassium nitrate), charcoal, and sulfur, haven't changed since ancient times.

When the fuse in the fireworks is lit, the black powder ignites and produces gases that propel the firework into the air. Charcoal gives the firework a sparkling, flaming tail. Energy is necessary to start the reaction in a fireworks display. If the fireworks are not packed correctly, the thermal reaction fails, resulting in what we call a "dud."

The shells of fireworks contain the ingredients that create the explosions. Inside the shells, black powder and other chemicals are packed in layers. When ignited, one layer may cause a bright burst of light. Another layer produces a booming sound. The shell's shape affects the shape of the explosion. Cylindrical shells produce a trail of lights that looks like an umbrella. Round shells produce a starburst design.

The color and sound of fireworks depend on the chemicals used. To create colors, chemicals like strontium for red, magnesium for white, and copper for blue can be mixed with the black powder. Sodium creates a yellow colored light. Barium and nickel are used for green. Lithium, strontium, and calcium produce different shades of red.

Fireworks are launched from metal, plastic, or cardboard tubes. Black powder explodes, but only if it is packed tightly into a small space. In firecrackers, for example, the black powder is packed very tightly. The fireworks that are launched into the night sky have black powder, too, but one end is not packed tightly. The gases formed from the burning black powder escape out of the bottom of the shell. The force created, called thrust, moves out of the bottom of the shell downward. The "equal and opposite" reaction causes the rocket to go upward. The black powder burns quickly, but it can propel the firework high into the sky. Then more black powder packed differently inside the shell makes the shell explode in the sky. The same scientific principles that help

pyrotechnicians create fireworks also help scientists launch the space shuttle.

There are two main methods of producing color in fireworks. **Incandescence** is light produced from heat. Heat causes the chemicals to get hot and glow. As they begin to glow, they emit infrared, and then red, orange, yellow, and white light as they get hotter and hotter. When the temperature of a firework is controlled, the glowing of the chemicals used can be manipulated to be the desired color at a certain time. Metals such as aluminum, magnesium, and titanium burn very brightly. They are used to increase the temperature of the firework.

The other method of producing color is luminescence. **Luminescence** is light produced using energy sources other than heat. Sometimes luminescence is called "cold light" because it can happen at room temperature or cooler temperatures. To produce luminescence, energy is absorbed by an electron of an atom or molecule, causing it to become excited and unstable. When the electron returns to a lower energy state, the energy is released in the form of a photon (light). The energy of the photon determines its wavelength and color.

Careful planning is required. Too much smoke or residue can mask the colors. Pure colors require pure ingredients. Even trace amounts of impurities are enough to overpower or change the other colors. The skill of the manufacturer affects the final display. Cost is often related to quality. The fireworks used during a New Year's Eve or Fourth of July celebration can cost anywhere from $200 to $2,000 each. So the next time you're enjoying a fireworks display, think of the years of experimentation, the careful making of each firework, and the total cost involved to make you "ooh" and "ahh."

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Questions

_____ 1. The colors in a fireworks display depend on:

A. the wavelengths of light emitted by different chemicals as they burn
B. raindrops in the atmosphere
C. amount of heat inside the firework
D. all of the above

_____ 2. In which country was gunpowder invented long ago?

A. Japan
B. Greece
C. United States
D. China

_____ 3. What does the word "pyrotechnics" mean?

A. fire art
B. explosions
C. gunpowder
D. fireworks

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_____ 4. Which ingredient in fireworks gives the firework a sparkling, flaming tail?

A. saltpeter
B. gunpowder
C. black powder
D. charcoal

_____ 5. What is the force called that is created by the burning of the black powder?

A. equal and opposite
B. thrust
C. pyrotechnics
D. lift

_____ 6. What is incandescence?

A. light produced from other energy sources besides heat
B. light produced from heat
C. cold light
D. photons

_____ 7. What is luminescence?

A. light produced from other energy sources besides heat
B. photons
C. light produced from heat

_____ 8. What materials are used to increase the temperature of the firework?

A. metals such as aluminum, titanium, and magnesium
B. black powder and nitroglycerine
C. charcoal and saltpeter
D. cardboard and plastic shells

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How many of these can you write about? Think! Write! Check all the ones you answered.

- ☐ Would you like to be a pyrotechnician? Explain why or why not.
- ☐ If you were to design the "perfect" firework, what would it look like? Explain how you would build it.

Don't stop writing. Use a blank piece of paper to continue.