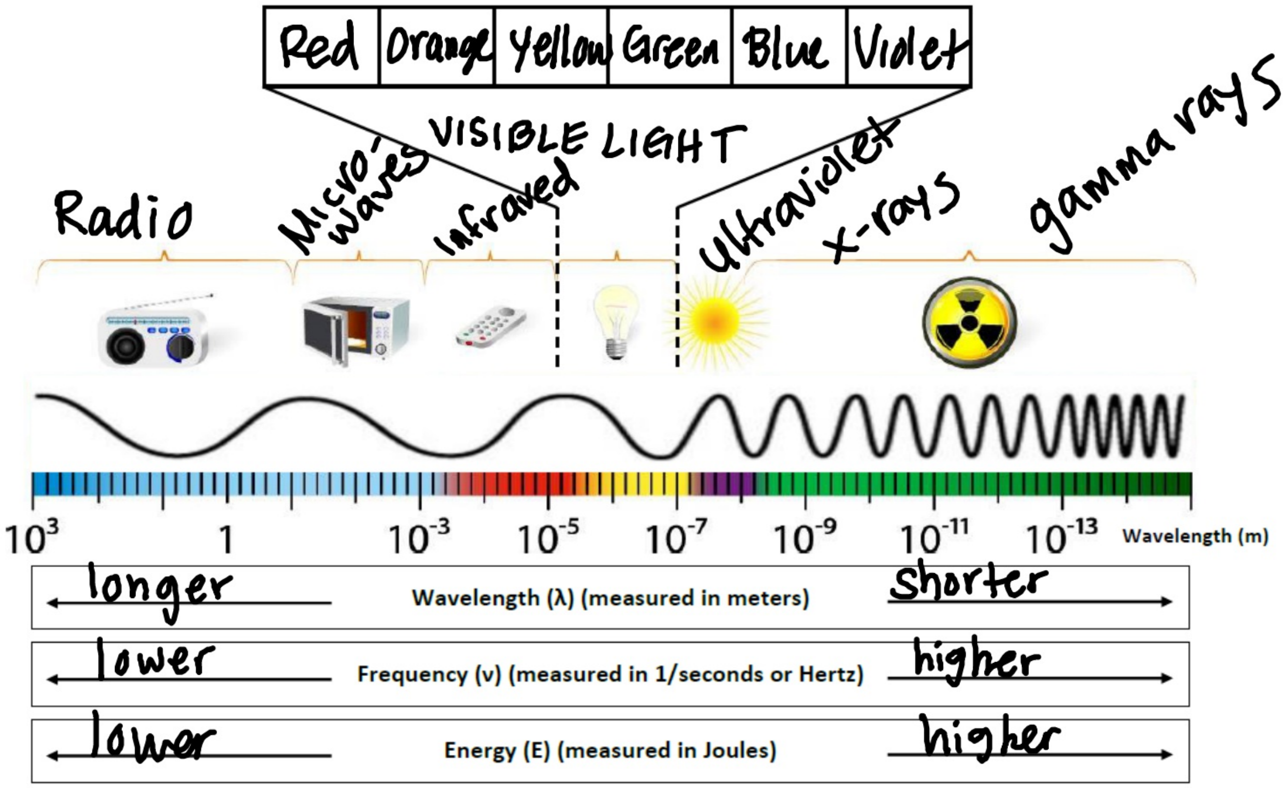
THE ELECTROMAGNETIC SPECTRUM



Fireworks...How Do They Work?

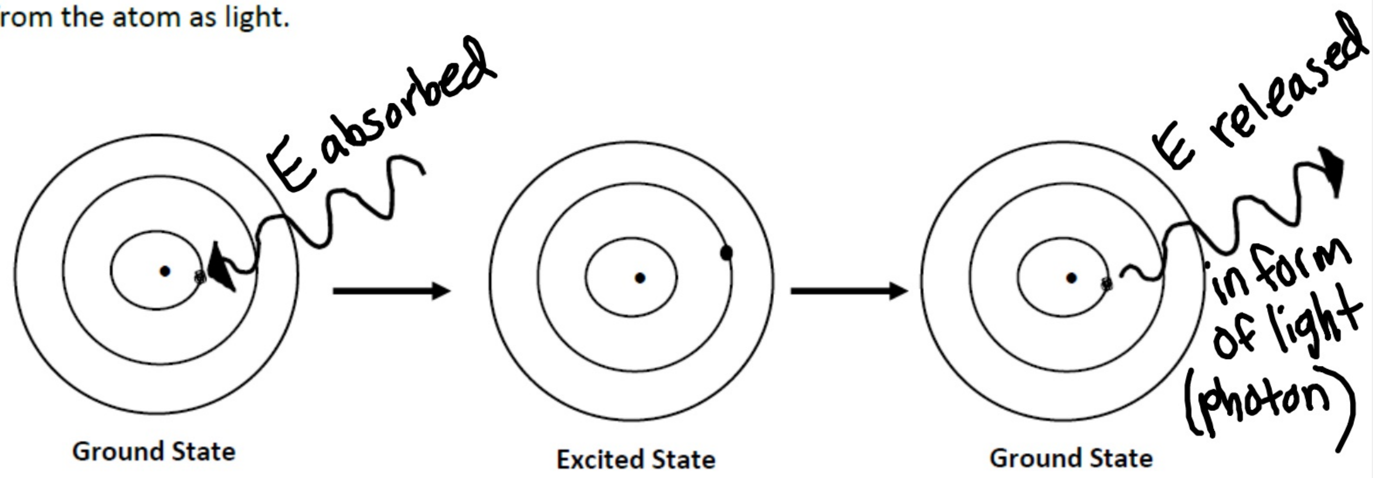
Fireworks…How Do They Work?

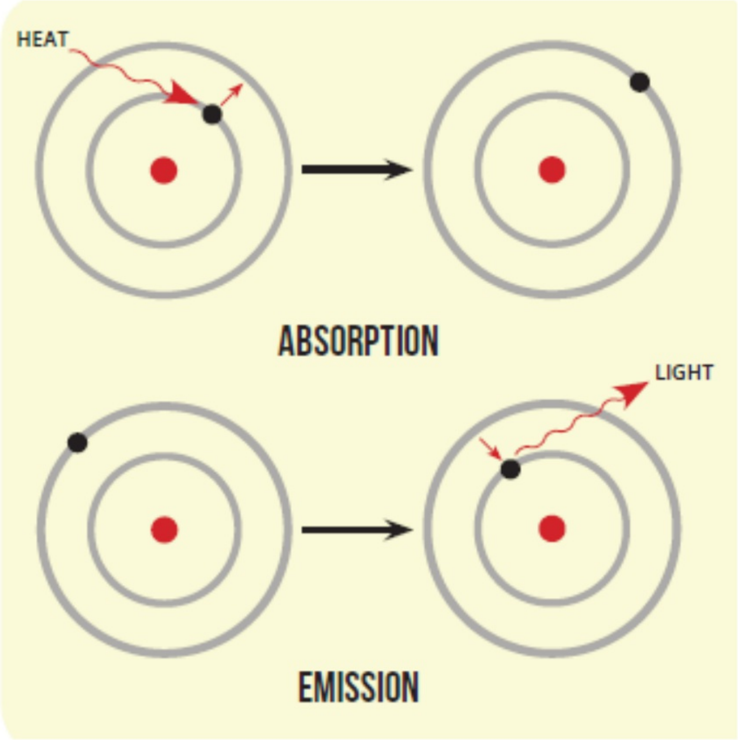

© Can Stock Photo

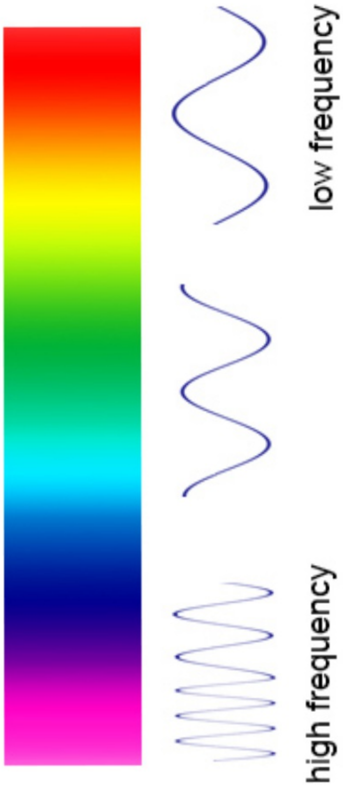
Fireworks are known for their spectacular display of colored lights, but how are these different colors produced? The wide variety of colors is due to the different metal salts that make up the fireworks. A "salt" is an ionic compound, thus a metal salt is an ionic compound made of a metal ion and a nonmetal ion bonded together. When the metal salt is ignited with a fuel source, energy is released in the form of light. The type of metal in the salt determines the color of the light. Therefore, every metal produces a specific color.

Why is light produced?

When the fuel source in the fireworks burns a lot of heat is produced. This heat causes the electrons in the metal atoms to gain energy and be excited to higher energy levels. These excited states are unstable, so the electron quickly returns to its original energy level (ground state). Since the electron loses energy as it moves to a lower energy level, energy is released from the atom as light.

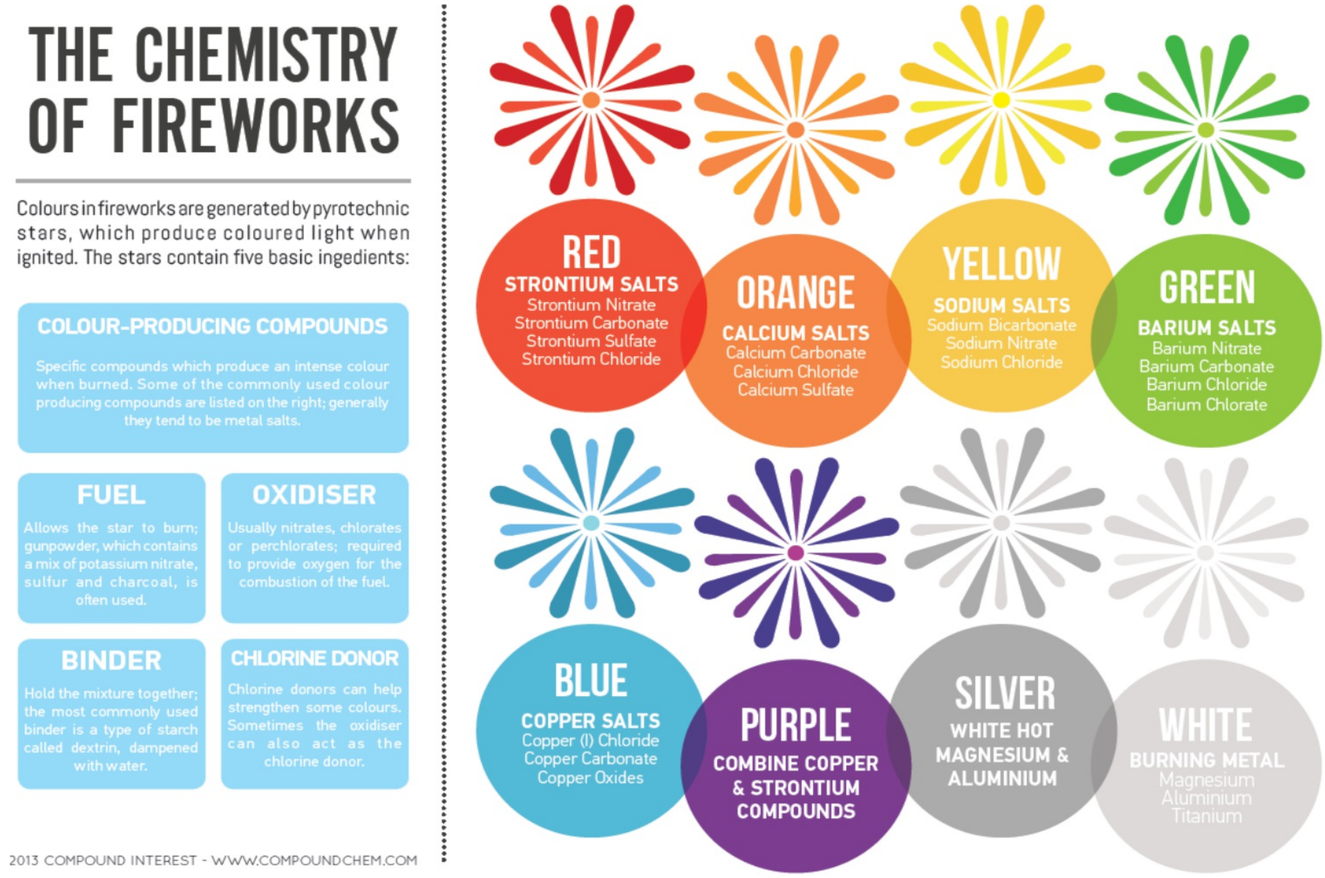






What determines the color of light produced?

A photon is a packet of light with a specific amount of energy. Every photon from the electromagnetic spectrum travels at the speed of light, but not every photon contains the same amount of energy. Each color of the rainbow contains photons of a specific amount of energy. For example, red light contains a different amount of energy than blue light. Therefore, in fireworks, the amount of energy released from the atom as the electron moves to a lower energy level determines the color of light. Different metals will have different energy gaps between their ground and excited states, leading to the emission of different colors.



THE CHEMISTRY OF FIREWORKS

Colours in fireworks are generated by pyrotechnic stars, which produce coloured light when ignited. The stars contain five basic ingedients:

COLOUR-PRODUCING COMPOUNDS

Specific compounds which produce an intense colour when burned. Some of the commonly used colour producing compounds are listed on the right; generally they tend to be metal salts.

FUEL

Allows the star to burn; gunpowder, which contains a mix of potassium nitrate, sulfur and charcoal, is often used.

OXIDISER

Usually nitrates, chlorates or perchlorates; required to provide oxygen for the combustion of the fuel.

BINDER

Hold the mixture together; the most commonly used binder is a type of starch called dextrin, dampened with water.

CHLORINE DONOR

Chlorine donors can help strengthen some colours. Sometimes the oxidiser can also act as the chlorine donor.

2013 COMPOUND INTEREST - WWW.COMPOUNDCHEM.COM

RED
STRONTIUM SALTS
Strontium Nitrate
Strontium Carbonate
Strontium Sulfate
Strontium Chloride

ORANGE
CALCIUM SALTS
Calcium Carbonate
Calcium Chloride
Calcium Sulfate

YELLOW
SODIUM SALTS
Sodium Bicarbonate
Sodium Nitrate
Sodium Chloride

GREEN
BARIUM SALTS
Barium Nitrate
Barium Carbonate
Barium Chloride
Barium Chlorate

BLUE
COPPER SALTS
Copper (I) Chloride
Copper Carbonate
Copper Oxides

PURPLE
COMBINE COPPER & STRONTIUM COMPOUNDS

SILVER
WHITE HOT MAGNESIUM & ALUMINIUM

WHITE
BURNING METAL
Magnesium
Aluminium
Titanium

Energy Formulas

Formulas	Variables / Constants
$c = \lambda\nu$	c = speed of light = $\frac{3.00 \times 10^8 \text{ m}}{s}$ λ = wavelength, measured in nanometers 1 nm = 10^{-9} m ν = frequency, measured in $\frac{1}{s}$ = s^{-1} = Hz 1 THz = 10^{12} Hz
$E = h\nu$	E = energy, measured in Joules (J) h = Planck's constant = 6.626×10^{-34} J•s ν = frequency, measured in $\frac{1}{s}$ = s^{-1} = Hz 1 THz = 10^{12} Hz

Energy Practice Problems

1. Calculate the $\overset{\lambda}{\boxed{\text{wavelength in meters}}}$ of yellow light emitted from a sodium lamp if the frequency is $\underset{\nu}{\underline{5.10 \times 10^{14}\text{ Hz}}}$. Calculate the wavelength of the light in nanometers.

$$c = \lambda \nu$$

$$\frac{\left(3 \times 10^{8} \frac{m}{\cancel{s}}\right)}{5.10 \times 10^{14} \frac{1}{\cancel{s}}} = \frac{\lambda \left(5.10 \times 10^{14} \frac{1}{s}\right)}{5.10 \times 10^{14} \frac{1}{s}}$$

$$\boxed{5.88 \times 10^{-7}\,m = \lambda}$$

$$\frac{5.88 \times 10^{-7}\,\cancel{m}}{} \left| \frac{1\ \text{nm}}{1 \times 10^{-9}\,\cancel{m}} \right. = \boxed{588\ \text{nm}}$$

2. Ultraviolet radiation has a frequency $\underset{\nu}{\underline{\text{of } 6.8 \times 10^{15}\text{ Hz}}}$. Calculate the $\underset{?E}{\boxed{\text{energy, in joules}}}$ of the photon.

$$E = h\nu$$

$$E = \left(6.626 \times 10^{-34}\,J \cdot \cancel{s}\right)\left(6.8 \times 10^{15} \frac{1}{\cancel{s}}\right)$$

$$\boxed{E = 4.5 \times 10^{-18}\ J}$$

3. A certain photon of radiation has a frequency of $\overset{\nu}{\underline{\text{73 THz.}}}$ Calculate the $\overset{\lambda}{\boxed{\text{wavelength, in meters,}}}$ of this photon. From which type of radiation of the electromagnetic spectrum does this photon belong?

$$c = \lambda \nu$$

$$\frac{\left(3\times10^{8}\,\frac{m}{\cancel{s}}\right)}{7.3\times10^{13}\,\frac{1}{\cancel{s}}} = \frac{\lambda\left(7.3\times10^{13}\,\frac{1}{s}\right)}{7.3\times10^{13}\,\frac{1}{s}}$$

$$\boxed{\lambda = 4.1\times10^{-6}\ m}$$

$$\boxed{\text{Infrared}}$$

$$\begin{array}{c|c} 73\ \text{THz} & 1\times10^{12}\ \text{Hz} \\ \hline & 1\ \text{THz} \end{array}$$

$$\nu = 7.3\times10^{13}\ \text{Hz}$$