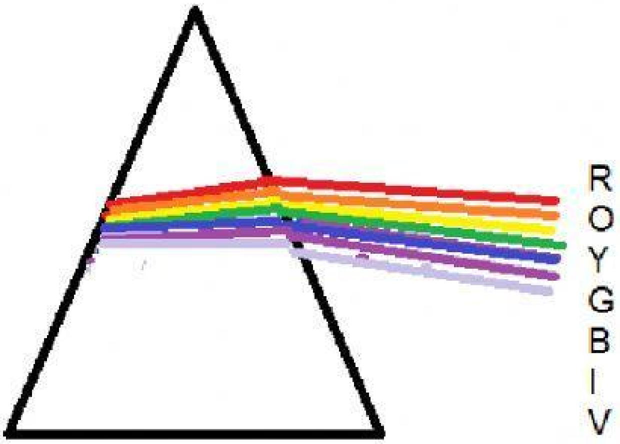
Atomic Emission Spectrum

(see Physics notes pg 366-369)

A **continuous emission spectrum** is seen when white light passes through a prism. When you shine white light through a prism, you find out that it contains a rainbow of colors. This is called **dispersion**, and it happens because light of different wavelengths, or colours, refracts, or bends, by different amounts inside the prism.



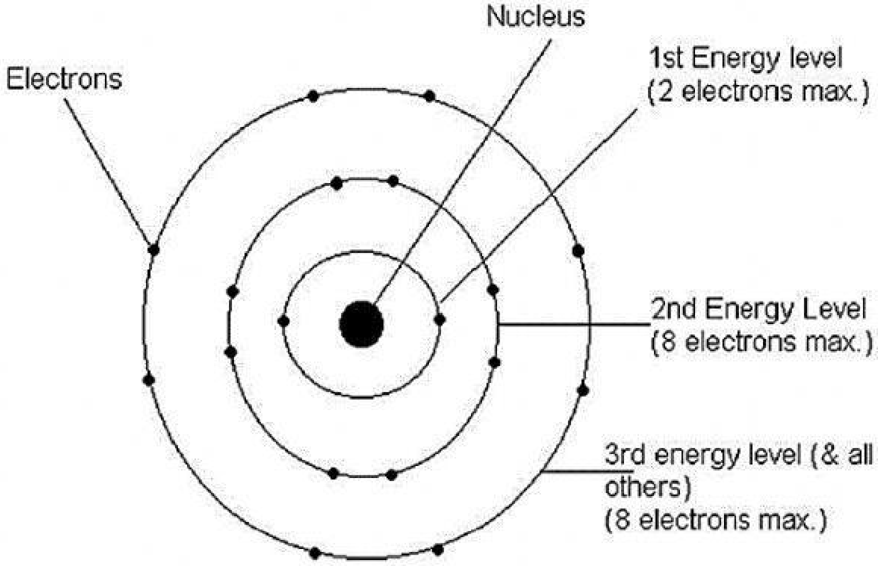
Colour	Wavelength range (nm)
violet	390 - 455
blue	455 - 492
green	492 - 577
yellow	577 - 597
orange	597 - 622
red	622 - 780

Light is emitted (given off) by very hot objects (light bulb, sun). When something is heated, the frequency of vibration of the atoms increases. Then charges radiate electromagnetic waves at the same frequency as vibrating charges. When the frequency is high enough, visible light is produced.

Red is seen first when objects are heated because it has the lowest frequency. As the temperature increases, frequency of vibration of atoms increases and other colours are seen (in order from red to violet).

When a metal rod is put into the fire and it gets hot enough, eventually there are atoms vibrating at all possible frequencies and white light is seen.

<u>When atoms of a gas are heated</u>, the electrons of the gas become excited (that means they gain energy). Remember that electrons in an atom are contained in shells or **energy levels**. Electrons have a fixed amount of energy within each energy level. Electrons in energy levels further from nucleus possess more energy than electrons that are closer to the nucleus.



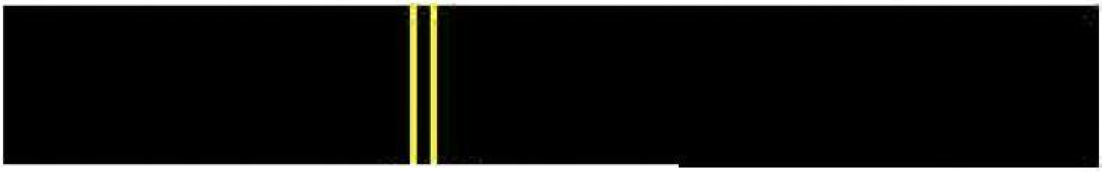
Electron Energy Levels

http://mychemistry11.blogspot.com/2010/10/bohrs-model.html

When an electron is excited it 'jumps' to a higher energy level, but it is **unstable** in that state. Thus the electron almost immediately falls back to lower, more stable energy level. In the process of falling back down, it loses the energy it had gained. This energy is radiated or **emitted** in the form of a quantum of light (fixed amount of energy).

Example:

If you look at a hot sodium flame through a diffraction grating, then 2 yellow lines are seen. This is known as an **emission spectrum** and the emission spectrum for sodium will always look the same. (The function of the **diffraction grating** is simply to disperse the light, in the same way a prism does in the example above.)



In general:

- When you look at any element's flame (or when an electric current is passed through an element's vapors), it emits light. Each element displays its own unique set of lines (colours) due to the electron structure of the atom (almost like a "fingerprint" for the element).
- Separate bright lines of different colours are seen, each representing a single frequency of light (and fixed energy of light emitted by gas).
- The amount of energy emitted must be equal to the difference between 2 energy levels in the atom. Therefore only certain energies / frequencies of light are able to be emitted. Thus only certain colours appear in an element's atomic emission spectrum.

  Example:

  - If an electron was excited from energy level n=2 up to n=5, then it must return from n=5 to n=2 when it loses the energy. A photon with energy = difference of (level 5 - level 2) is released. The energy of that photon would be high (blue light).
  - If an electron jumps to n=3 and returns to n=2, a smaller energy photon is released (red light).

Remember:

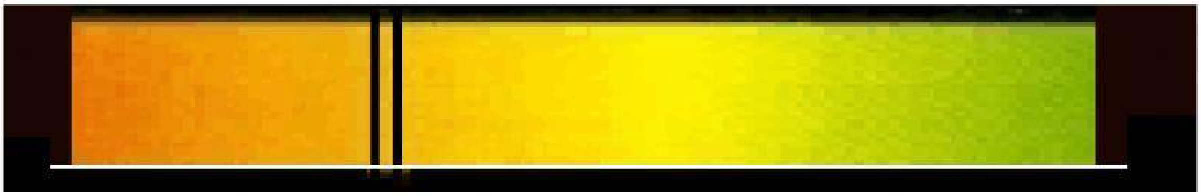
Blue = shortest wavelength Highest frequency Highest energy	**Red** = longest wavelength Lowest frequency Lowest energy

Atomic Absorption Spectrum

- This phenomenon is the opposite of what we have learned above with Atomic Emission spectra.
- It is obtained when white light is passes through a **cold, dilute gas** and the atoms in the gas **absorb** photons of characteristic frequencies. (Instead of a hot gas emitting photons.)
- The light transmitted by the gas then produces a spectrum **without** the absorbed frequencies. These gaps appear as dark, black lines in the spectrum. Each line represents a wavelength of light (and therefore a quantity of energy) that was absorbed by the gas.

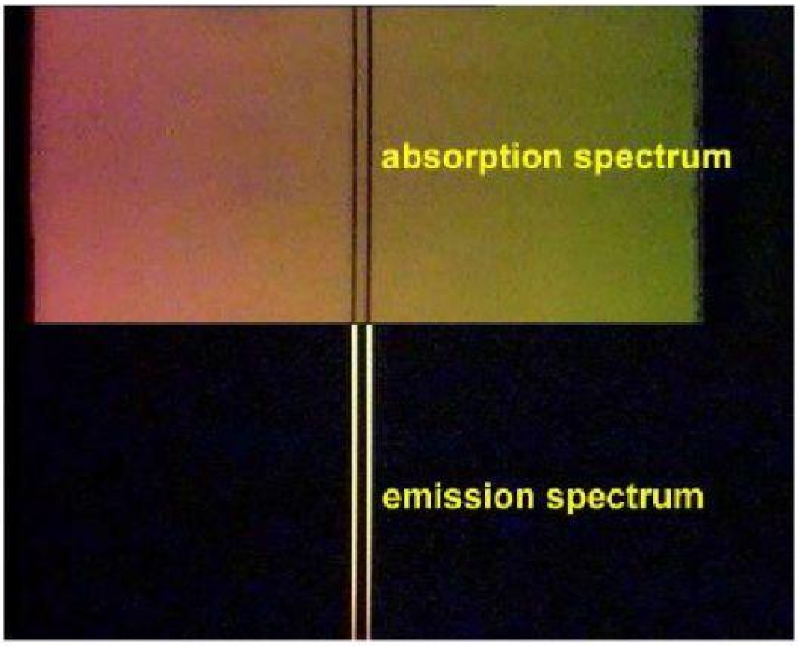
Example:

If white light is passed through cold sodium gas the spectrum below will be observed:



- The photons absorbed by the cold gas have the same energy value as the photons emitted by the hot sodium gas! 2 black lines are seen in the yellow portion of continuous spectrum.
- When the electrons in the atoms of the gas absorb a photon, it is excited from a lower to a higher energy level. The excited electron then drops down to a lower (more stable) energy level again. The energy is then re-emitted as a photon, but it is unlikely that photon will be emitted in the same direction as original photon. Thus transmitted light produces spectrum containing dark line (frequencies absorbed by atoms of the gas).
- If you add the emission line spectrum to the absorption line spectrum (for a particular element) you would get a continuous spectrum.

  e.g. for sodium – if you overlap the 2 images, you would have a complete spectrum of light



We said that the Absorption Spectrum is like the opposite of the Emission Spectrum – let's compare the two:

Table comparing emission and absorption spectrum

Emission spectrum	**Absorption spectrum**
Electrons move from higher to lower energy level	Electrons move from lower to higher energy level
Photons of specific energy are emitted	Photons of specific energy are absorbed
Formed by hot gases under low pressure	Formed when white light passes through a cold gas

Watch this YouTube video which further explains Atomic Emission and Absorption Spectra:

https://www.youtube.com/watch?v=2ZlhRChr_Bw

Exercise – EMR and Emission & Absorption Spectra

Question 1:

Give one word/phrase for the following:

1.1 Electromagnetic waves with the highest penetrating ability.

1.2 The "packets of energy" making up electromagnetic radiation.

1.3 Electromagnetic radiation with the longest wavelength.

1.4 The type of line spectrum observed when electrons in an atom move from the excited state to the ground state. EMISSION / ABSORPTION

Question 2:

Rank red, green and yellow light from LARGEST to SMALLEST according to:

2.1 wavelength _____ > _____ > _____

2.2 frequency _____ > _____ > _____

2.3 energy _____ > _____ > _____

Question 3: Multiple Choice

3.1 Which ONE of the following correctly represents the given types of electromagnetic radiation in order of INCREASING WAVELENGTH?

A. microwaves, infrared, ultraviolet

B. infrared, ultraviolet, X-rays

C. radio waves, infrared, gamma rays

D. ultraviolet, infrared, microwaves

3.2 Cut glass is used to make ornaments. In light it shows all the colours of the rainbow. Which ONE of the following is NOT an explanation for this observation?

A. White light consists of a spectrum of colours.

B. Each colour in white light is refracted by different amounts in glass.

C. Cut glass has its own characteristic colours.

D. White light splits into colours of different frequencies as it passes through glass.

3.3 Which ONE of the following electromagnetic waves has the shortest wavelength?

A. radio waves

B. gamma rays

C. infrared rays

D. ultraviolet rays

3.4 Which ONE of the following descriptions best explains the formation of a line emission spectrum?

A line emission spectrum is formed when....

A. white light passes through a cold gas

B. white light passes through a triangular prism

C. electrons in the ground state move to a higher energy level

D. electrons in the excited state move to a lower energy level

3.5 Overexposure to sunlight causes damage to plants and crops. Which ONE of the following types of electromagnetic radiation is responsible for this damage?

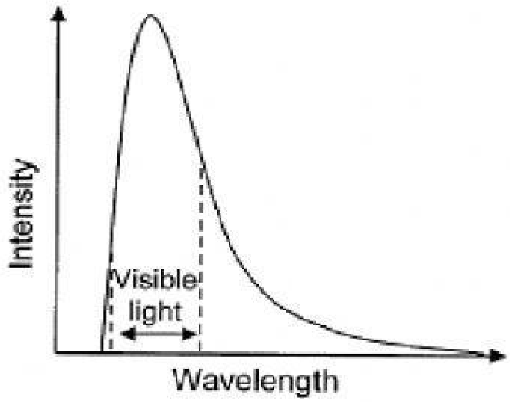
A. ultraviolet rays

B. radio waves

C. visible light

D. X-rays

3.6 Sunlight is composed of various intensities of the different wavelengths of light. The graph below represents the relationship between the intensity and wavelength of sunlight. The region between the dashed lines indicates the range of wavelengths of the visible portion of the spectrum.



Which colour of the visible part of sunlight has the lowest intensity?

A Red

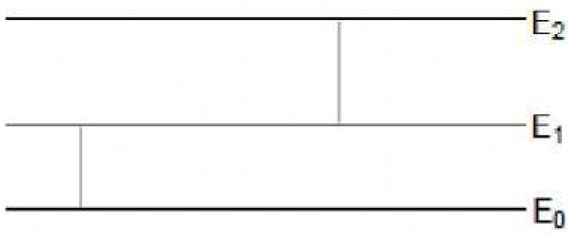
B Green

C Blue

D Violet

3.7

The energy level diagram for an element is shown below. E_0 represents the ground state. The energy change from E_0 to E_1 is smaller than that for E_2 to E_1.



The electron transition from E_2 to E_1 corresponds to a green line in the element's spectrum. The transition E_0 to E_1 corresponds to ...

A absorption of green light.

B emission of green light.

C emission of red light.

D absorption of red light.