

TYPES OF LIGHT EMISSION

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There are many sources of light.

Some sources of light are natural, for example the Sun. Other sources of light are artificial, i.e. those produced through human technology, such as candles, a fire and light bulbs.

For all light sources, whether natural or artificial, atoms within the material initially absorb the energy.

The absorbed energy excites the atoms, these excited atoms immediately release the absorbed energy upon returning to the unexcited state, (i.e. the ground state).

The released energy is then observed as light.

Luminous: refers to a source that produces its own light, example the Sun.

Non-luminous: a source that does not produce its own light, example a light bulb, a flashlight and a lit match.

Light from the Sun

The natural light produced by the Sun is a result of nuclear reaction known as a **fusion reaction**. Hydrogen atoms in the core of the Sun combine, (i.e. fuse) to produce helium.

A tremendous amount of energy is released during this fusion reaction.

This fusion energy is transmitted to the gases on the outer layers of the Sun.

The excited atoms release some of this energy in the form of light.

Light from Incandescence [pronounced: in-can-Des-ence]

Definition: Incandescence means light that is emitted by an object because of the high temperature of the material.

When heat energy is supplied to an object it gets hotter and hotter, the colours of light produced change from red, to orange, to yellow, to white, and then to bluish-white.

This process of producing light as a result of high temperatures is called incandescence.

Examples of light produced by an incandescence object are light from a burning candle, light bulbs, molten glass, and lit sparks flying off a grinder.

An incandescent light bulb has a thin tungsten wire called a filament that gets very hot, (to a temperature of $\sim 2500\text{ }^{\circ}\text{C}$), and glows brightly when an electric current is passed through it. The filament gets so hot that it gives off visible light.

The electric current generates the heat (due to infrared light emitted) that excites the atoms. These light bulbs are called *incandescent light bulb*.

[Incandescent light bulbs are filled with a gas such as nitrogen or argon because these gases do not react the hot tungsten filament instead of oxygen. Because these gases do not react with the tungsten, the filament does not burn out when it is repeatedly heated.]

An incandescent light bulb is inefficient at producing light, only 5 % to 10 % of the electricity going through the filament is converted into visible light.

The rest of the energy is converted into infrared light (as heat).

Light from Electric Discharge

Definition: the process of producing light by passing an electric current through the air or a gas.

The lightning produced during a thunderstorm is an example of an electric discharge through a gas.

Another example is the Aurora Borealis, or Northern Lights, seen in Northern regions. These shifting light patterns are caused by streams of charged particles from the sun passing through the upper atmosphere.

The development of an electric discharge in gas tubes was a result of the invention of a vacuum by Heinrich Geissler (1855).

The vacuum pump is used to evacuate most of the air from a closed electric discharge tube which has an electrode at each end.

A small amount of the element (i.e. sodium, Hg, Ne, Ar or Kr) is placed in the tube.

An electric current passes through the vapour and excites the atoms of the vapour of the gas in the discharge tube.

Electric charges move rapidly between the electrodes, colliding with the atoms in the vapour and thus exciting them.

When the excited atoms release their energy, they emit the light of a characteristic colour depending on the vapour in the electric gas discharge tube.

Na: yellow

Ne: red

He: gold-colour

Ar: pale violet-blue

Kr: grayish off-white

Hg: blue – green light

[By mixing different gases, any colour of light can be produced.]

Uses:

street lamps, neon signs for a business, mercury vapour lamps are used to light sports stadiums at night..

Carbon-arc light sources are used to produce searchlights, the beams reflect off of the bottoms of high clouds. A carbon– arc light involves passing an electric current through the air between two carbon rods. (Carbon-arc lights were also used in lighthouses.)

Light from Phosphorescence [pronounced: fos-for-ES-ence]

Definition: visible light that is emitted due to exposure of the source to ultraviolet light, and that continues to be emitted for an extended period of time in the absence of the ultraviolet light.

Phosphorescence is the ability of a material to store the energy from a source of light and then emit it slowly over a long period.

Phosphorescent materials glow in the dark for some time after being energized by light.

Because light is emitted over a period of time, phosphorescent materials are often described as “glow - in - the - dark”

Phosphors absorb light energy primarily in the ultraviolet region. These materials keep some of the energy and release visible light of lower energy.

Uses: dials on wristwatches and clocks, glow in the dark stickers and bracelets or necklaces.

[Note: watch dials made in the early 20th century were made of a paint containing the radioactive element radium]

Light from Fluorescence [pronounced: flor-ES-ence]

The process of fluorescence is named after the mineral fluorite.

Fluorite glows when it is illuminated with ultraviolet light.

(Note: many other naturally occurring minerals also fluoresce in brilliant colours when exposed to ultraviolet light.)

Definition: visible light that is emitted as a result of the absorption of ultraviolet light.

Fluorescent light tubes are the most common application of fluorescence.

How a Fluorescent Light Tube Works

A fluorescent tube is an electric discharge tube with an electrode at each end.

The fluorescent tube is filled with mercury vapour at very low pressure.

The inside of the fluorescent tube is coated with a fluorescent powder such as phosphorus powder.

When electric energy charges the electrodes, they emit electrons.

When these electrons collide with the mercury vapour, they excite the mercury atoms.

The mercury atoms release their excess energy in the form of ultraviolet light, this is absorbed by the phosphorus lining of the fluorescent tube causing them to emit visible light.

[note: that this process is not quite the same as producing light by passing an electric current through a gas, as above. In the case of the fluorescent tube, the ultraviolet light produced by the electric current cannot be seen. However the visible light observed is a result of the light produced by the phosphorus coating after it absorbs the ultraviolet light.]

Diagram of the fluorescent tube:

Fluorescent lighting is more efficient (~ 4-5 times more efficient) at producing light than incandescent lighting. A fluorescent light can provide the same amount of visible light but produces much less heat and uses less electricity.

The disadvantage of fluorescent lights is that they contain mercury and should therefore not be disposed of with regular household waste.

Although the purchase price of fluorescent lights is higher, their lifetime costs are lower because they use less electricity and last longer.

Uses of Fluorescence

Fluorescent materials are found in many places:

1. Many body fluids contain fluorescent molecules. Forensic investigators use ultraviolet lights at crime scenes to find blood, urine and semen (all fluorescent).
[Investigators use a chemical called luminol to detect traces of blood because the chemical glows when it reacts with the iron found in blood.]
2. The tongue's natural fluorescence changes when abnormal tissue is present. Abnormalities can be detected by a dentist or a hygienist.
3. By theater performers: when the theater is in darkness and only ultraviolet light is shining on the performer, the audience is able to see the fluorescence light coming from the paint used by the performer.
4. Laundry detergents: manufacturers often add fluorescent dyes to their detergents, because normal daylight includes a small amount of ultraviolet light. The fluorescent dye on the clothing absorbs the ultraviolet light and emits visible light. The eye detects both this emitted light and the normally reflected light from the material, so the material looks bright.
5. Highlighter pens: the ink in these pens contain a fluorescent dye that causes the ink to glow in the presence of ultraviolet part of normal daylight.

Luminescence: [pronounced: loo-mi-NES-ence]

Definition: Luminescence is the emission of light by a material or an object that has not been heated.

The energy used to excite the atoms can come from a variety of sources.

Chemiluminescence, Bioluminescence, and Triboluminescence are types of luminescence.

1. **Light from Chemiluminescence** [pronounced: CHE-mi-loo-mi-NES-ence]

Definition: is light that is produced by a chemical reaction without a rise in temperature.

Almost no heat is produced as a result of this type of reaction, hence it is sometimes called ‘cool light’.

Light sticks, and glow sticks, emergency lighting are examples of light produced by chemiluminescence.

How Light Sticks Operate

Light sticks and glow -in-the-dark bracelets/necklaces are plastic tube with chemical A with an inner glass capsule with chemical B.

Bending the glow stick causes the glass capsule to break.

Upon mixing chemical A and B, their chemical reaction produces visible light. A dye in the solution causes the colour of the light.

Light sticks are inexpensive to manufacture, they are very durable, and since light sticks do not require an electric current thus they are very useful in hazardous environments where a spark could be quite dangerous.

2. **Light from Bioluminescence** [pronounced: BIH-OH-loo-miNES-ence]

Definition: the production of light in living organisms as the result of a chemical reaction with little or no heat produced.

This is chemiluminescence in living organisms.

Bioluminescence is common in many living organisms such as certain bacteria, fungi, fish, fireflies, glow-worms and marine invertebrates.

Bioluminescence is used by living organisms to protect themselves from predators, to lure prey, or to attract mates.

3. **Light from Triboluminescence** [comes from the Greek word *tribein*, meaning to rub, and from the Latin word *lumen*, meaning light.]

Triboluminescence is the production of light from friction as a result of scratching, crushing or rubbing certain crystals.

Triboluminescence may be observed when sugar cubes are broken apart, or when quartz crystals are rubbed or crushed or when a diamond is rubbed.

ASSIGNMENT: TYPES OF LIGHT EMISSION

1. What does 'excited atom' mean, and what happens after an atom is excited/
2. Explain the meaning of incandescence.
3. What do all incandescent materials have in common to cause them to emit light?
4. Why is an incandescent bulb a very inefficient light source?
5. Why are incandescent light bulbs being eliminated from widespread use?
6. What is phosphorescence?
7. How is ultraviolet radiation produced in a fluorescent light transformed into visible light?
8. What is the difference between phosphorescence and fluorescence?
9. Do fluorescent whiteners or optical brighteners in detergents really make clothes cleaner?
10. Predict whether or not a fluorescent material would glow if it was illuminated by infrared light.
11. What type of light is produced by a glow-in-the-dark object?
12. Predict whether or not a light stick would be a good light source in a potentially explosive environment. Explain your prediction.
13. Describe one difference between chemiluminescence and bioluminescence.
14. Classify each of the following types of light according to its source:
 - a. Firefly
 - b. Lightning
 - c. Glow sticks
15. Is a glow-in-the-dark dial on a watch or clock an example of phosphorescence or fluorescence? Explain your answer.
16. What is the term used to describe the process in which light is produced by rubbing materials together?
17. Suggest several ways to provide emergency lighting where you need it if the power goes out. Consider factors such as brightness, duration, and cost.
18. Black light refers to any light source that produces primarily ultraviolet radiation.
 - a. Provide a possible reason why it is called black light.
 - b. Describe a use for black light.
19. What is a possible disadvantage of using fluorescent bulbs?