The Effect Of Temperature On Light Intensity Of Different Coloured Glow Sticks

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INTERNATIONAL SCHOOL

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ABSTRACT

Light energy is a form of electromagnetic radiation. Light consists of photons, which are produced when an object's atoms heat up. Light travels in waves and is the only form of energy visible to the human eye. It is possible to produce light without heat or electricity. **Chemiluminescence** is the emission of light caused by a chemical reaction. This type of luminescence can be observed by bending and shaking a light stick.

I wanted to visualize how temperature impacts the light intensity of glowing sticks. My project aims at studying the relationship between the colour of the glow-stick with the light intensity at three different temperatures. For this purpose, I had used the commercial glow-sticks which I bought from Amazon. I had chosen five different colours as White, Pink, Lime-green, Yellow and Orange for my study. For measuring the intensity of light produced, I constructed the light measuring device by making use of Light Detecting Resistor (LDR) also known as photoresistor. I completely wrapped three glass jars using aluminium foil leaving the open end, in order to ensure no light is escaped. I inserted the photo-resistor through the hole made in the three lids and well-insulated them. The resistance exhibited by the photoresistor is the measure of the light intensity produced from the glow-sticks. I connected the exposed leads of photo-resistor with the multimeter. Before proceeding, the photoresistor was tested for its baseline in open lid and closed lid condition. Then, I started twisting the glow-sticks and putting inside the empty glass jar setups to measure the light intensity at room temperature which is followed by ice-cold water and hot water baths for all the five colours. At a time, I have done three trials for all the cases. The multimeter reading which shows the resistance in kilo-ohms (kΩ) was taken at every minute for 15 minutes. The average readings were tabulated and plotted into graph. I observed the greater increase in the photo-resistance in ice cold water from that of hot and room temperatures, which implies low light intensity. I formulated that ***increasing temperature actually increases light intensity*** unless and until the heat is maintained. Comparing all colours, ***Yellow has more light intensity in all the temperatures.***

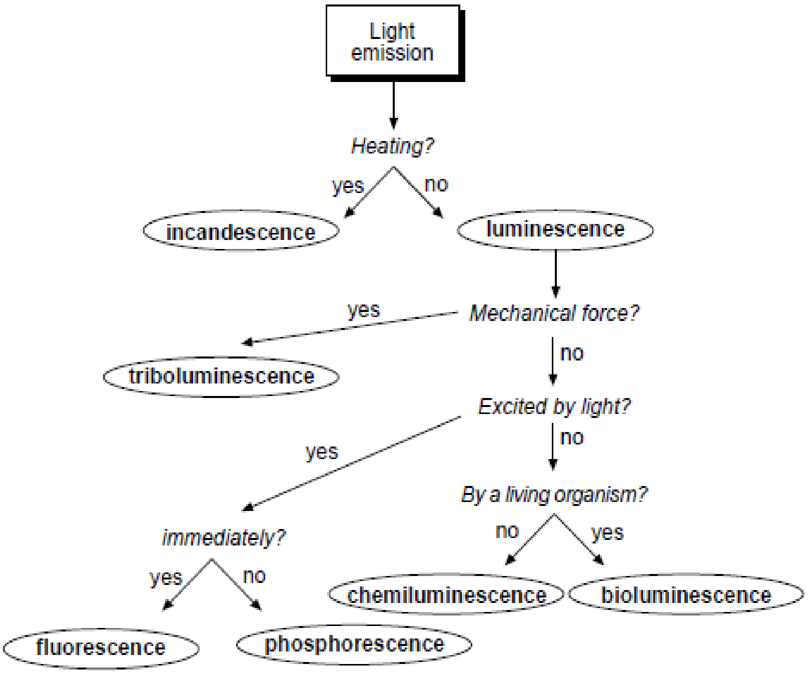
INTRODUCTION

Light energy is used to help us see – either naturally using the Sun or fire, or with manmade objects like candles or light bulbs. Light energy is also used by plants, which capture the light energy from the Sun and use it to produce their food. Light is made up of photons, which are like tiny packets of energy. When an object's atoms heat up, photons are produced from the movement of atoms. The hotter the object, the more photons are produced. The word “photon” comes from Latin word photo – which means light.

Figure 1: ***Glow Worms are capable for producing their own light - Bioluminescence***

Cold light

Cold light is also known as luminescence. It is light that is emitted when things are cold. Light emitted when things get hot is called incandescence – for example, the light from a Bunsen burner, a standard light bulb or an electric cooker when hot. There are many types of cold light, given different names depending on the conditions under which the light is emitted.



How glow sticks glow?

All liquid glow products depend on a chemical process known as Chemiluminescence to produce their light. Chemiluminesence is a chemical reaction that causes a release of energy in the form of light. To produce this light the electrons in the chemicals become excited and rise to a higher energy level. To utilise this process glow-sticks contain two liquids; hydrogen peroxide and tert-butyl alcohol. When mixed together it is these liquids that create the glow. Fluorescent dyes are also used in the alcohol to alter the colour of the light emitted.

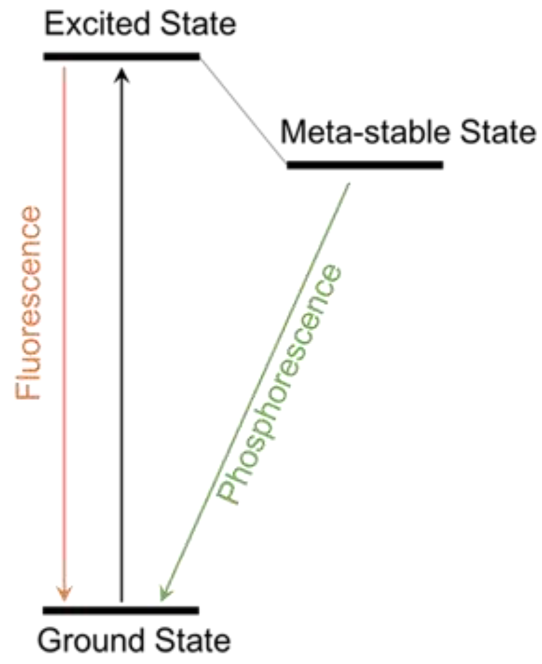
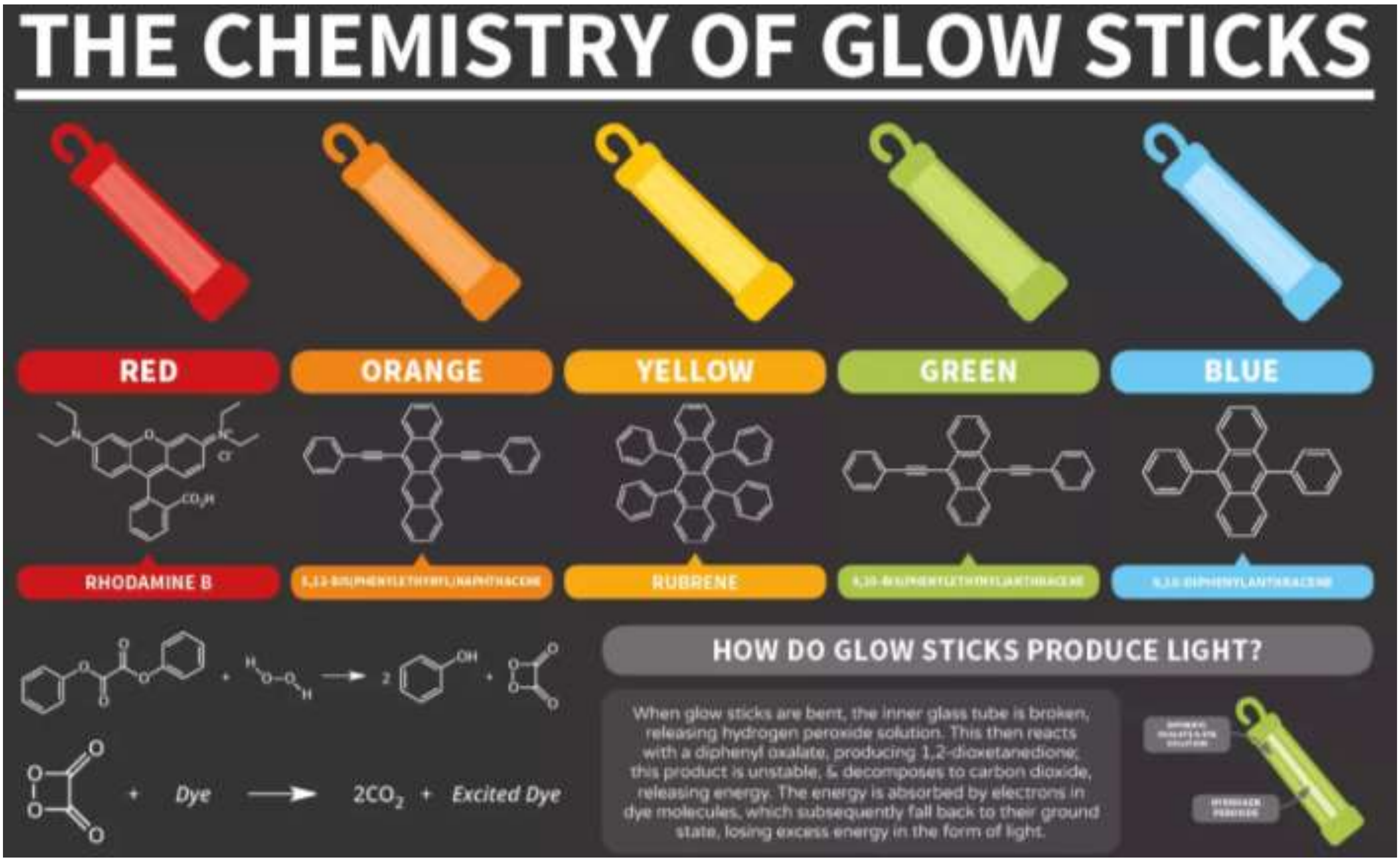


Figure 1: Energy scheme that shows phosphorescence and fluorescence.

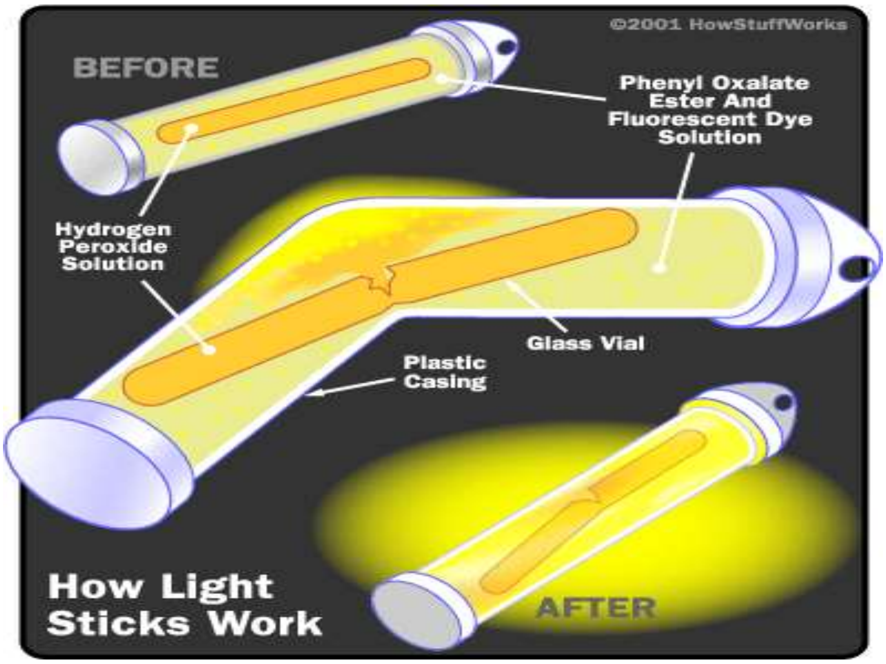
When photons interact with a material, electrons can be excited from the ground state to an excited state. When they return to the ground state, they release their energy in the form of light (fluorescence). Electrons can also be trapped in a meta-stable state and when these electrons relax to the ground state they release light by phosphorescence.

When the stick bends, the glass vial breaks allowing the two liquids to mix together. One of the liquids is contained in a very fine glass tube that floats within the mixture inside the plastic glow stick product. This is why you must bend a glow stick to make it start glowing. When the stick bends, the glass vial breaks allowing the two liquids to mix together. The chemical reaction begins immediately resulting in a bright, fantastic glow.



How long does a glow stick glow for?

The duration of glow stick's glow will vary depending upon the type of liquids used, the exact composition and also the quality of the liquids inside. Temperature also affects the intensity of the glow - the warmer it is the brighter the glow but this shortens the total glow duration. The colder it is the glow stick will glow less but will glow for a longer duration.



Chemiluminescence of luminol

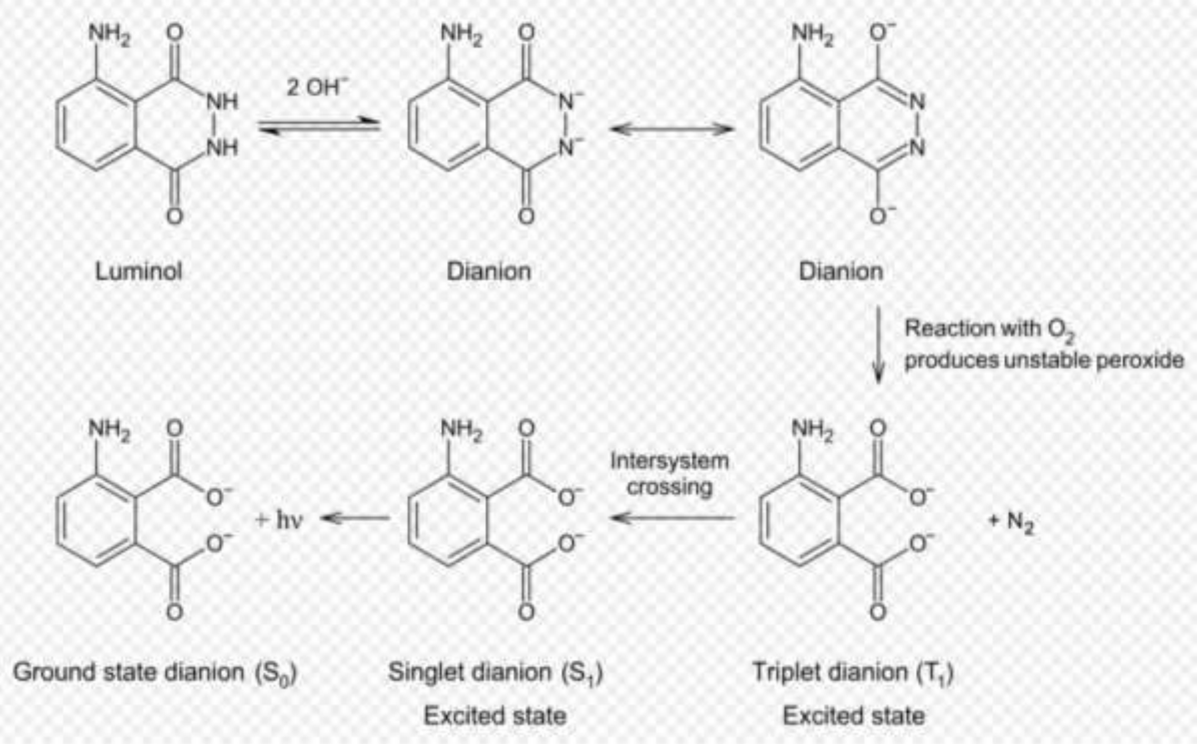
To exhibit its luminescence, the luminol must be activated with an oxidant. Usually, a solution containing hydrogen peroxide (H_2O_2) and hydroxide ions in water is the activator. In the presence of a catalyst such as an iron or periodate compound, the hydrogen peroxide decomposes to form oxygen and water:

$$2\ H_2O_2 \rightarrow O2 + 2\ H_2O$$

$$H_2O_2 + KIO_4 \rightarrow KIO_3 + O_2 + H_2O$$

Laboratory settings often use potassium ferri-cyanide or potassium periodate for the catalyst. In the forensic detection of blood, the catalyst is the iron present in haemoglobin. Enzymes in a variety of biological systems may also catalyse the decomposition of hydrogen peroxide.

Luminol reacts with the hydroxide ion, forming a di-anion. The oxygen produced from the hydrogen peroxide then reacts with the luminol dianion. The product of this reaction, organic peroxide, is very unstable and immediately decomposes with the loss of nitrogen to produce 5-aminophthalic acid with electrons in an excited state. As the excited state relaxes to the ground state, the excess energy is liberated as a photon visible as blue light.



Similarities and differences between chemi-luminescence and phosphorescence:

Fluorescence and phosphorescence are two mechanisms that emit light or examples of photoluminescence. However, the two terms don't mean the same thing and don't occur the same way. In both fluorescence and phosphorescence, molecules absorb light and emit photons with less energy (longer wavelength), but fluorescence occurs much more quickly than phosphorescence and does not change the spin direction of the electrons.

Fluorescence Versus Phosphorescence

1. Both fluorescence and phosphorescence are forms of photoluminescence. In a sense, both phenomena cause things to glow in the dark. In both cases, electrons absorb energy and release light when they return to a more stable state.
2. Fluorescence occurs much more quickly than phosphorescence. When the source of excitation is removed, the glow almost immediately ceases (fraction of a second). The direction of the electron spin does not change.
3. Phosphorescence lasts much longer than fluorescence (minutes to several hours). The direction of the electron spin may change when the electron moves to a lower energy state.

Examples of Phosphorescence

Phosphorescent materials are used in gun sight, glow-in-the dark stars, and paint used to make star murals. The element phosphorus glows in the dark, but not from phosphorescence.

Luminescence is the emission of light produced by methods other than heat. Luminescence is caused by the movement of electrons into different energetic states. There are many different types of luminescence including bioluminescence, chemiluminescence, phosphorescence, and fluorescence. These various forms of luminescence differ in their method of emitting light.Fluorescent and phosphorescence are only two ways light may be emitted from a material.

Chemiluminescence is the emission of light caused by a chemical reaction. ***Chemiluminesence is a chemical reaction that causes a release of energy in the form of light***.This type of luminescence can be observed by bending and shaking a light stick. Inside the light stick is an encapsulated chemical solution, surrounded by a different chemical solution. Bending the light stick causes the encapsulated chemical solution to break open. Shaking the light stick then causes the two solutions inside the stick to mix. When these chemicals combine, energy is created in the form of light. Organisms that emit light, known as bioluminescent organisms, also produce light through a chemical reaction.

Phosphorescence is the ability of a material to absorb energy from an electromagnetic radiation source, such as a flashlight, and then continue to emit light after the source has been removed. In this activity, the glow in the dark object absorbs or stores the energy from the flashlight and then gradually re-emits the energy as light, even after the flashlight has been turned off.

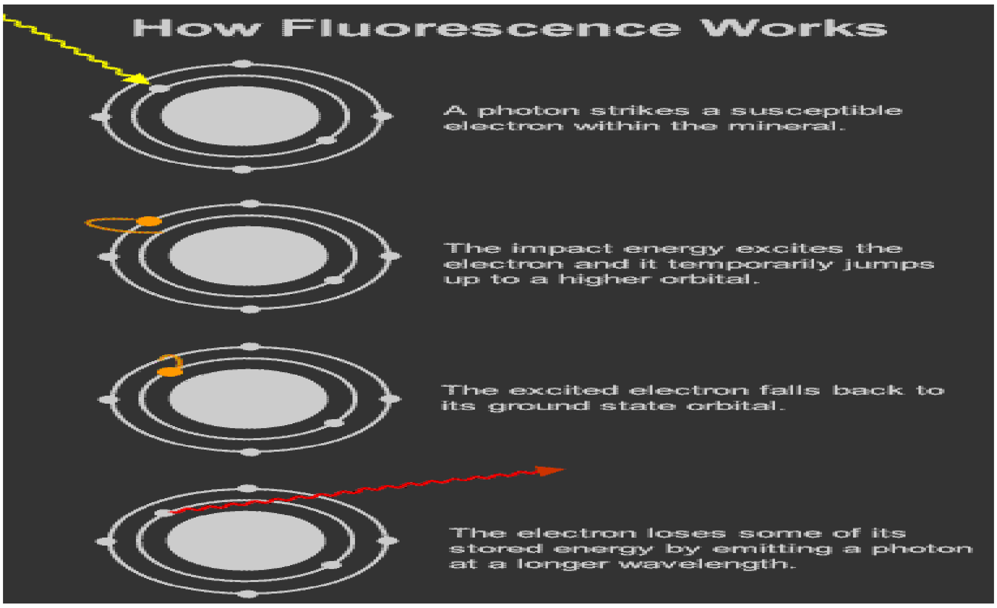
Fluorescence is similar to phosphorescence, in that it is the ability of a material to emit light by absorbing energy from a source of electromagnetic radiation. However, unlike phosphorescence, fluorescent materials can only emit light during the time that they are exposed to the source of electromagnetic radiation. A fluorescent material will stop "glowing" once the light source is removed.

Factors Affecting Fluorescence Efficiency

Structural Rigidity: Collisional deactivation is a major fluorescence quenching mechanism. Therefore, molecules possessing rigid structures are better fluorescers than others which lack rigidity. This explains why fluorene is an excellent fluorescer while biphenyl is a weak one.

Temperature: As temperature is increased, the translational, rotational and vibrational motions of molecules increase. This increases the possibilities of collisions and lead to collisional deactivation and quenching of fluorescence. Therefore, it is always wise to conduct fluorometric measurements at low temperatures

pH: Usually, fluorescers that contain either acidic or basic moieties have fluorescence quantum yields dependent on pH. The pH of these substances should be adjusted so that maximum fluorescence is obtained. (Future Enhancement)



Photoresistor

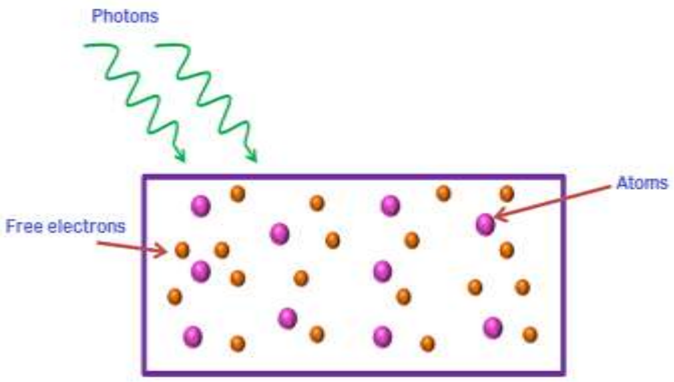
The name photoresistor is the combination of words: photon (light particles) and resistor. A photoresistor is a type of resistor whose resistance decreases when the intensity of light increases. In other words, the flow of electric current through the photoresistor increases when the intensity of light increases.

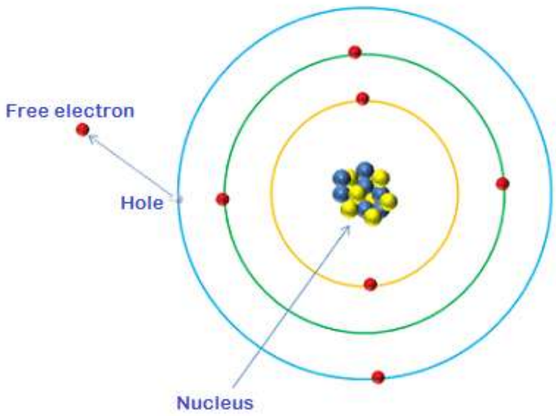
Photo-resistors are also sometimes referred as LDR (Light Dependent Resistor), semiconductor photoresistor, photoconductor, or photocell. **Photoresistor changes its resistance only when it is exposed to light.**

How photoresistor works?

When the light falls on the photoresistor, some of the valence electrons absorbs energy from the light and breaks the bonding with the atoms. The valence electrons, which break the bonding with the atoms, are called free electrons.

When the light energy applied to the photoresistor is highly increased, a large number of valence electrons gain enough energy from the photons and breaks the bonding with the parent atoms. The large number of valence electrons, which breaks the bonding with the parent atoms will jumps into the conduction band.

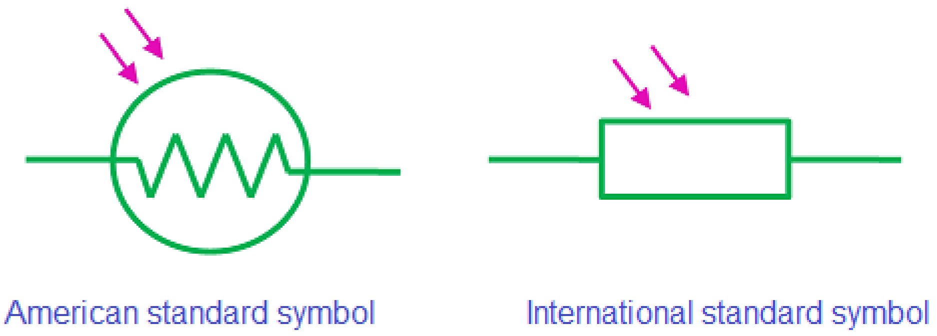




The electrons present in the conduction band do not belong to any atom. Hence, they move freely from one place to another place. The electrons that move freely from one place to another place are called free electrons. When the valence electron left the atom, a vacancy is created at a particular location in an atom from which the electron left. This vacancy is called as hole. Therefore, the free electrons and holes are generated as pairs.

The free electrons that are moving freely from one place to another place carry the electric current. In the similar way, the holes moving in the valence band carry electric current. Likewise, both free electrons and holes will carry electric current. The amount of electric current flowing through the photoresistor depends on the number of charge carriers (free electrons and holes) generated.

When the light energy applied to the photoresistor increases, the number of charge carriers generated in the photoresistor also increases. As a result, the electric current flowing through the photoresistor increases. Increase in electric current means decrease in resistance. Thus, the resistance of the photoresistor decreases when the intensity of applied light increases.



Photoresistors are made of high resistance semiconductor such as silicon or germanium. They are also made of other materials such as cadmium sulfide or cadmium Selenide.

In the absence of light, the photoresistors acts as high resistance materials whereas in the presence of light, the photoresistors acts as low resistance materials.

Types of photoresistors based on material used to construct them

Photoresistors are classified into two types based on the material used to construct them:

- Intrinsic photoresistor
- Extrinsic photoresistor

STATEMENT OF THE PROBLEM

There is no more saying that light can be produced only with electricity. Nature gifts everything that we can’t even think of. Light from Sun, firefly and much more we are seeing around gives us a hint of how to make use of them. This is how glow-sticks came into existence. But how extent it may direct way-lost souls in foggy and freezing nights, and which colour lasts long are all a matter of concern now. Hence, it is necessary to know the impact of temperature and colour on how long or brighter will be the glow.

HYPOTHESIS

Cold temperature increases the Light intensity of glow sticks.

DESIGN OF STUDY

INDEPENDENT VARIABLE:

- **Experiment 1:** Temperature
- **Experiment 2:** Colour

DEPENDENT VARIABLES:

- Resistance of Photo Resistor
- Glowing Time

CONTROLLED VARIABLES:

- **Experiment 1:** Length Of The Glow Stick, Amount Of Chemicals Responsible For Chemiluminescence, Colour
- **Experiment 2:** Length Of The Glow Stick, Amount Of Chemicals Responsible For Chemiluminescence, Temperature

MATERIALS:

- Photo-resistor - 3
- Digital multimeter -3
- Alligator clip leads with connecting wires- 3 sets
- Glass jar with lid, big enough to hold glow-in-the-dark-objects -3
- Glow bracelets (Pink, orange, lime-green, yellow and white of length 8”) each 10
- Aluminum foil roll
- Black electrical tape
- Lighting candle and a thin metal wire (for putting hole in the plastic lid)
- Laboratory thermometer
- Liquid measuring cup
- Heat-resistant cup
- Induction stove and a vessel for heating water
- Tap water
- Ice cubes
- Timer or stopwatch
- Lab notebook

PROCEDURE:

- Decide on the surroundings where the setup could be set in.

Building the Light-Measuring Device:

1. In this project, we need to determine the light intensity so that we can compare the longevity and the brightness of the glow with respect to the colour. Build up the Light measuring device with the help of photo-resistor.
2. A photo-resistoror light-dependent resistor, LDR, or photo-conductive cell is a light-controlled variable resistor. The resistance of a photo-resistor decreases with increasing incident light intensity. Photo-resistor is a small, round part, with a squiggly line on the front and two metal leads.
3. Make the light-measuring device by wrapping the glass jar in aluminum foil and taping a photo-resistor in the lid with electrical tape.
   a. Wrap aluminum foil around the sides of the glass jar so no light gets in and seal all edges securely with black electrical tape.
   b. Light up the candle and heat one end of a thin metal wire. With the hot wire, considering the resistor head size put two holes nearby in the centre of the plastic lid at once.
   c. Insert the photo-resistor through the hole in the inside of the lid so that the metal leads could be visible outside. Tape the photo-resistor over the hole in the jar top, so it is facing inside the jar when the lid is closed (the side with the squiggly line should be facing the inside of the jar).
   d. Leave a small amount of exposed metal at the ends of the leads, so we can attach alligator clips to them later. If the jar lid is made of metal, also cover the metal lid with electrical tape.
   e. Bend the leads of the photo-resistor sideways and cover them in electrical tape, so they do not bump into each other and create a *short circuit*.

Important: Do not let the leads of the photo-resistor touch the aluminum foil. Make sure to insulate the aluminum foil and the leads with electrical tape; otherwise it will create a short circuit and the resistance of the photo-resistor will always read zero.

Testing the resistance baseline:

1. Determine the resistance baseline for the measuring device and measure the resistance of the photo-resistor for the jar with nothing in it and with the lid on and off.
   a. Set up the measuring device in a room with as few disturbances in lighting as possible. The photo-resistor is very sensitive, so variations in sunlight coming through a window on a cloudy day, or

even shadows and reflections created as people walk around the room, can all affect the readings if we did not seal the glass jar properly.

b. Set up the multimeter to measure the resistance of the photo-resistor.
   i. Plug the black multimeter probe into the port labelled COM.
   ii. Plug the red multimeter probe into the port labelled VΩmA.
   iii. Connect the multimeter probes to the leads of the photo-resistor using alligator clips. Make sure the metal parts of the alligator clips do not touch the aluminum foil, or this will create a short circuit.
   iv. Set the multimeter dial to measure resistance in the 200 kilo-ohm (kΩ) range.
   v. Turn the power switch ON.
c. Leave the lid open and expose the photo-resistor to the surrounding light. Read the resistance across the photo-resistor and record it in the lab notebook.
   i. Note the units of the resistance. A "k" indicates kilo-ohms (kΩ).
   ii. If the multimeter screen displays a "1.", that means the resistance is too high for the dial setting. Turn the dial up to the next highest range (for example, from 200 k to 2000 k) and check again.
d. Close the jar with the photo-resistor lid and read the resistance across the photo-resistor again. In the dark, the resistance should be in the mega-ohm range. Remember that we may need to adjust the dial setting to get a measurement. Record the resistance in your lab notebook. *Note*: The light level in the closed, light-protected (aluminum-foil-wrapped) jar should be the same when the jar is in a lighted room or in a dim room. If it changes, that means there is a light leak. Find the problem area and cover the light leak with electrical tape.
e. Get ready 2 more glass jars in the same way.

Setting up the glow sticks:

Once the photo-resistor is tested for its baseline, measure the luminescence as a function of resistance.

Measuring Luminescence

Using the light-measuring device, we can measure the light intensity of the glow sticks. To minimize unwanted variations, position the glow sticks in the jar the same way for each trial, keep movement of the setup to a minimum.

STEP I:

1. First, investigate how the light intensity of the glow-in-the-dark object changes over time.

a. Keep the glowsticks of different colours –White, Pink, Lime-green, Yellow and Orange each 10 in a tray.
b. First, start with White. Twist three white glow sticks to start the reaction. Make sure to shake it enough so that it glows evenly. Then bend it to form bracelets with the help of connectors.
c. Place each of three sticks in three aluminum-foil wrapped jar and place the lid on (3 trials). Set the timer to 15 minutes. Note down the starting time also.
d. Record the time and signal strength produced by the light of the glow stick every minute for 15 minutes.
e. Follow the same for other four colours each three trials.
f. After each colour, place the used sticks in a dark room to observe the time period of its glow. Note down the glowing time.

STEP II:

1. Next, investigate how temperature affects the light intensity of the glow-in-the-dark object.
   a. The first step can be included as the effect of temperature of the light intensity of glowing object ***at Room Temperature.***
   b. Once the 15 minutes are over, open the jar and add ***cold water*** to decrease the temperature, as follows:
      i. Prepare a cup of ice cold water by putting a couple of ice cubes in a cup of tap water.
      ii. Wait for a few minutes so as to attain a temperature range of 5-9°C. then remove the ice cubes.
      iii. Simultaneously, twist and bend the white sticks readily.
      iv. Open the jar, and fill the jar with the cold water so that the glowing object is fully submerged.
      v. Carefully close the jar again.
   c. Set the timer to 15 minutes and record the resistance of the glow-in-the-dark object in cold water once the 15 minutes are over.
   d. Follow the same for all the five colours and note down the reading.
   e. After each colour, keep the used sticks aside in the dark room under observation.

STEP III:

1. Next, open the jar and replace the cold water with hot water to increase the temperature, as follows:
   i. Prepare a cup of hot water (approximately 70°C-75°C) by heating some water on the stove. Check the temperature using thermometer.

ii. Carefully open the jar, pour out the cold water and re-fill the jar with the hot water so that the glowing object is fully submerged.

iii. Carefully close the jar again.

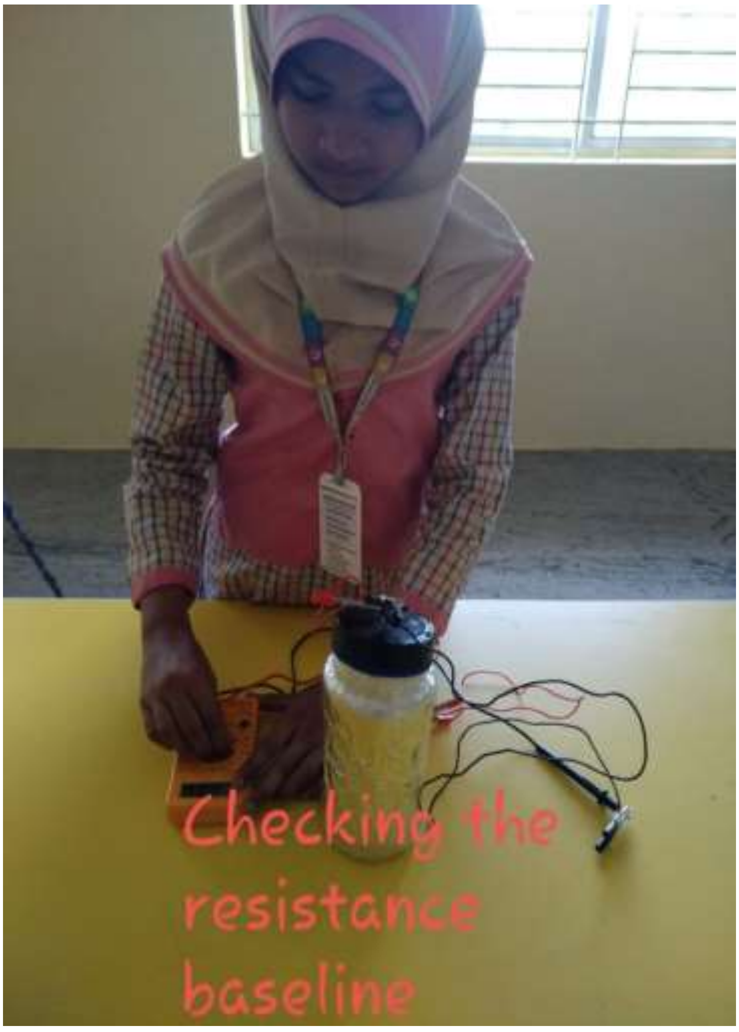
2. Set your timer to 15 minutes and record the resistance of the glow-in-the-dark object in hot water once the 15 minutes are over.
3. Follow the same procedure for 5 different colours (Pink, orange, lime-green, yellow and white) and compare the glowing time of different glow sticks under different temperature.

Analyzing Your Data

1. Calculate the average resistance for each of the time point (every minute) from all three of the trials each of the five colours. Plot the data showing the time, in minutes, on the x-axis, and the average resistance, in kOhms (kΩ), on the y-axis. The resistance curve should start with a low level at first and then gradually rise to a higher level as the light intensity decays. **The resistance of the photo-resistor *increases* with decreasing light intensity**.
2. With the help of the graph, visualize:
   - How the light signal decays with time.
   - How temperature affects the light intensity.
3. Make another data table with the temperature (room temperature, hot, and cold) and the average resistance readings (of three trials) in orkOhms (kΩ), of every minute (upto 15 minutes) for each colour. Graph results in a bar graph with the temperature on the x-axis and the resistance on the y-axis.

COLLECTION OF DATA- PHOTOGRAPHS


Insulating photoresistor

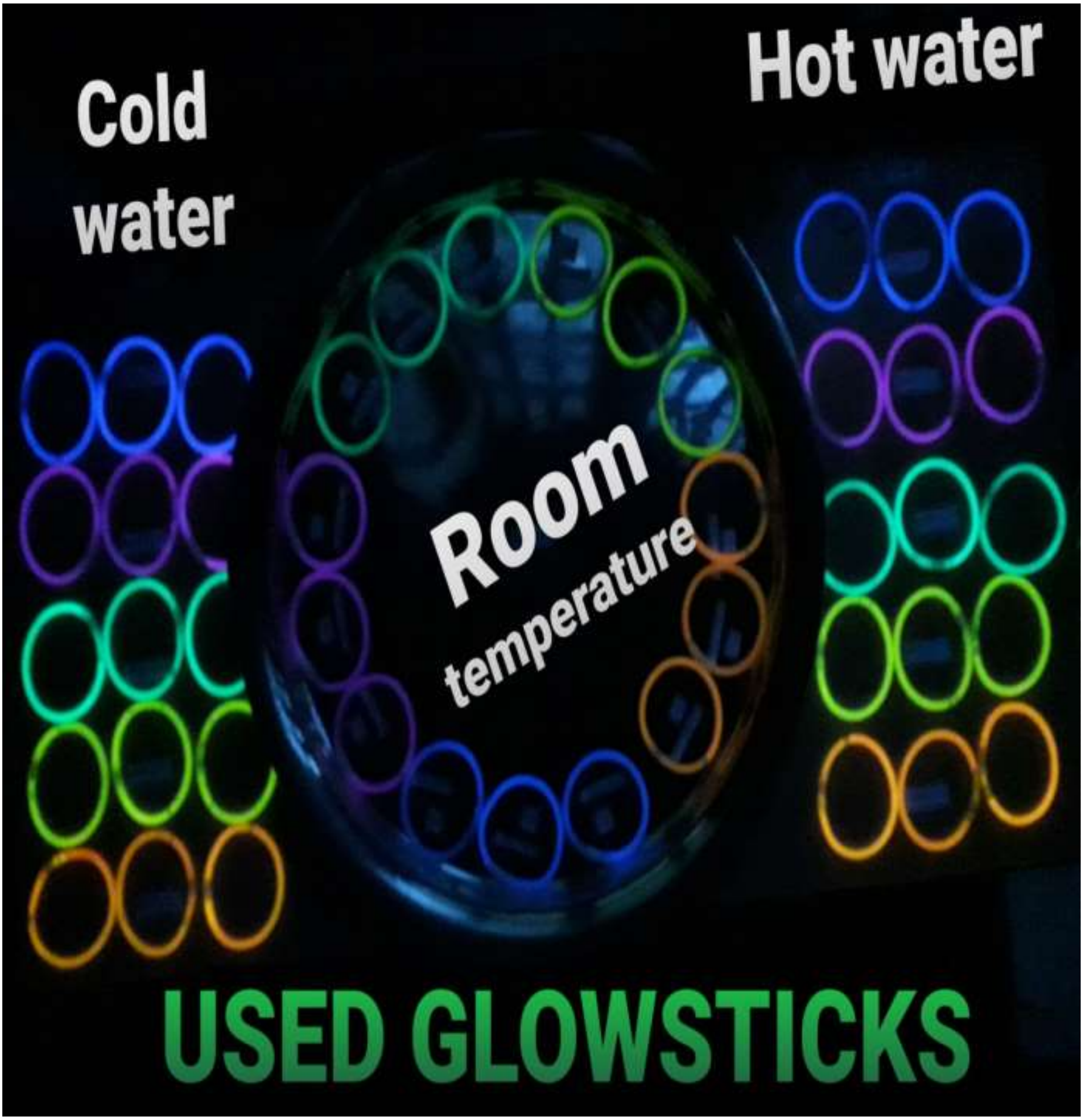

Checking the resistance baseline


Noting readings


Twisting
glowsticks


In flash


TRIAL_1
Green sticks
in water


Cold water
Hot water
Room temperature
USED GLOWSTICKS


Used
glowsticks in
dark room


Glow sticks in light
Samsung Dual Camera
Shot with Murshi's Galaxy M10

Tabulation

Table1: Measuring the Baseline of the Photo-resistor without glow sticks

	Photo-resistance with open lid (kΩ)	Photo-resistance with closed lid (kΩ)
Trial 1	15	Above 2000
Trial 2	16	
Trial 3	14	

Table 2: Effect of temperature on light intensity of WHITE coloured glow stick

Time (in minutes)	Photo-resistance (kΩ)											
	At room temperature 31°C				In Ice cold water at 9°C				In Hot water at 75°C			
	Trial 1	Trial 2	Trial 3	AVG	Trial 1	Trial 2	Trial 3	AVG	Trial 1	Trial 2	Trial 3	AVG
0	1379	183	177	**579.667**	2000	1007	1830	**1612.33333**	348	111	100	**186.333**
1	1500	234	242	**658.667**	2000	1128	1886	**1671.33333**	525	201	192	**306**
2	1600	262	296	**719.333**	2000	1164	1933	**1699**	616	248	212	**358.667**
3	1715	284	331	**776.667**	2000	1189	1975	**1721.33333**	740	286	240	**422**
4	1757	305	358	**806.667**	2000	1217	2000	**1739**	835	327	272	**478**
5	1817	318	380	**838.333**	2000	1245	2000	**1748.33333**	906	377	303	**528.667**
6	1861	331	397	**863**	2000	1269	2000	**1756.33333**	992	427	333	**584**
7	1885	342	411	**879.333**	2000	1281	2000	**1760.33333**	1084	482	367	**644.333**
8	1914	352	424	**896.667**	2000	1307	2000	**1769**	1171	526	402	**699.667**
9	1926	361	435	**907.333**	2000	1326	2000	**1775.33333**	1296	565	427	**762.667**
10	2000	368	445	**937.667**	2000	1342	2000	**1780.66667**	1360	604	450	**804.667**
11	2000	377	455	**944**	2000	1354	2000	**1784.66667**	1461	660	488	**869.667**
12	2000	384	463	**949**	2000	1376	2000	**1792**	1550	712	519	**927**
13	2000	390	471	**953.667**	2000	1387	2000	**1795.66667**	1681	803	549	**1011**
14	2000	397	480	**959**	2000	1397	2000	**1799**	**1773**	**829**	**577**	**1059.67**
15	2000	404	488	**964**	2000	1406	2000	**1802**	**1776**	**883**	**606**	**1088.33**

Time (in minutes)	***Photo-resistance (kΩ)***		
	At room temperature 31°C	***In Ice cold water at 9°C***	***In Hotwater at 75°C***
0	579.667	1612.33333	186.333
1	658.667	1671.33333	306
2	719.333	1699	358.667
3	776.667	1721.33333	422
4	806.667	1739	478
5	838.333	1748.33333	528.667
6	863	1756.33333	584
7	879.333	1760.33333	644.333
8	896.667	1769	699.667
9	907.333	1775.33333	762.667
10	937.667	1780.66667	804.667
11	944	1784.66667	869.667
12	949	1792	927
13	953.667	1795.66667	1011
14	959	1799	1059.67
15	964	1802	1088.33

Table 3 : Effect of temperature on light intensity of PINK coloured glow stick

Time (in minutes)	Photo Resistance (in kΩ)											
	At room temperature 31°C				In Ice cold water at 9°C				In Hot water at 75°C			
	Trial 1	Trial 2	Trial 3	AVG	Trial 1	Trial 2	Trial3	AVG	Trial 1	Trial 2	Trial 3	AVG
0	275	143	170	**196**	1798	1715	2000	**1837.66667**	148	87	59	**98**
1	331	173	217	**240.333**	1721	1796	2000	**1839**	216	170	95	**160.333**
2	372	196	247	**271.667**	1722	1808	2000	**1843.33333**	279	220	123	**207.333**
3	404	214	268	**295.333**	1809	1847	2000	**1885.33333**	324	266	147	**245.667**
4	431	229	283	**314.333**	1840	1871	2000	**1903.66667**	404	316	174	**298**
5	454	242	295	**330.333**	1860	1937	2000	**1932.33333**	464	371	198	**344.333**
6	473	252	306	**343.667**	1885	1951	2000	**1945.33333**	533	429	225	**395.667**
7	491	262	316	**356.333**	1894	1990	2000	**1961.33333**	591	476	246	**437.667**
8	507	270	325	**367.333**	1972	1996	2000	**1989.33333**	646	541	276	**487.667**
9	521	278	334	**377.667**	1950	1999	2000	**1983**	706	593	304	**534.333**
10	536	284	341	**387**	1966	2000	2000	**1988.66667**	782	658	332	**590.667**
11	549	291	350	**396.667**	1970	2000	2000	**1990**	845	724	361	**643.333**
12	560	297	358	**405**	1979	2000	2000	**1993**	914	790	390	**698**
13	573	303	366	**414**	1899	2000	2000	**1966.33333**	1045	849	418	**770.667**
14	579	309	374	**420.667**	1918	2000	2000	**1972.66667**	1109	928	448	**828.333**
15	597	314	381	**430.667**	1970	2000	2000	**1990**	1143	976	477	**865.333**

Time (in minutes)	*Photo-resistance (kΩ)*		
	At room temperature 31°C	***In Ice cold water at 9°C***	***In Hot water at 75°C***
0	196	1837.66667	98
1	240.333	1839	160.333
2	271.667	1843.33333	207.333
3	295.333	1885.33333	245.667
4	314.333	1903.66667	298
5	330.333	1932.33333	344.333
6	343.667	1945.33333	395.667
7	356.333	1961.33333	437.667
8	367.333	1989.33333	487.667
9	377.667	1983	534.333
10	387	1988.66667	590.667
11	396.667	1990	643.333
12	405	1993	698
13	414	1966.33333	770.667
14	420.667	1972.66667	828.333
15	430.667	1990	865.333

Table 4 : Effect of temperature on light intensity of LIME-GREEN coloured glow stick

Time (in minutes)	***Photo-resistance (kΩ)***											
	At room temperature 31°C				***In Ice cold water at 9°C***				***In Hot water at 75°C***			
	Trial 1	***Trial 2***	***Trial 3***	***AVG***	***Trial 1***	***Trial 2***	***Trial 3***	***AVG***	***Trial 1***	***Trial 2***	***Trial 3***	***AVG***
0	61	42	50	**51**	687	493	484	**554.666667**	39	24	18	**27**
1	86	60	61	**69**	687	502	509	**566**	76	42	31	**49.6667**
2	101	71	72	**81.3333**	708	506	538	**584**	90	52	37	**59.6667**
3	119	84	81	**94.6667**	725	510	555	**596.666667**	118	62	48	**76**
4	128	88	86	**100.667**	732	516	561	**603**	127	73	56	**85.3333**
5	132	91	91	**104.667**	741	518	568	**609**	160	84	64	**102.667**
6	135	94	94	**107.667**	746	521	575	**614**	178	93	73	**114.667**
7	143	99	102	**114.667**	759	528	586	**624.333333**	199	104	82	**128.333**
8	145	101	106	**117.333**	765	532	593	**630**	225	118	91	**144.667**
9	148	103	154	**135**	771	536	600	**635.666667**	246	132	99	**159**
10	151	107	161	**139.667**	779	542	607	**642.666667**	268	146	108	**174**
11	157	111	168	**145.333**	790	547	614	**650.333333**	295	160	119	**191.333**
12	160	117	121	**132.667**	801	555	625	**660.333333**	312	172	128	**204**
13	170	117	125	**137.333**	814	562	634	**670**	340	185	138	**221**
14	174	120	128	**140.667**	824	569	641	**678**	373	202	149	**241.333**
15	177	122	130	**143**	**829**	**574**	**647**	**683.333333**	402	215	160	**259**

Time (in minutes)	***Photo-resistance (kΩ)***		
	At room temperature 31°C	***In Ice cold water at 9°C***	***In Hot water at 75°C***
0	51	554.666667	27
1	69	566	49.6667
2	81.3333	584	59.6667
3	94.6667	596.666667	76
4	100.667	603	85.3333
5	104.667	609	102.667
6	107.667	614	114.667
7	114.667	624.333333	128.333
8	117.333	630	144.667
9	135	635.666667	159
10	139.667	642.666667	174
11	145.333	650.333333	191.333
12	132.667	660.333333	204
13	137.333	670	221
14	140.667	678	241.333
15	143	683.333333	259

Table 5 : Effect of temperature on light intensity of YELLOW coloured glow stick

Time (in minutes)	***Photo-resistance (kΩ)***											
	At room temperature 31°C				***In Ice cold water at 9°C***				***In Hot water at 75°C***			
	Trial 1	***Trial 2***	***Trial 3***	***AVG***	***Trial 1***	***Trial 2***	***Trial 3***	***AVG***	***Trial 1***	***Trial 2***	***Trial 3***	***AVG***
0	57	62	45	**54.6667**	528	540	353	**473.667**	20	16	16	**17.3333**
1	76	79	64	**73**	551	549	363	**487.667**	43	33	35	**37**
2	88	89	76	**84.3333**	573	549	367	**496.333**	61	45	47	**51**
3	98	97	85	**93.3333**	591	554	373	**506**	81	56	61	**66**
4	105	102	92	**99.6667**	610	562	379	**517**	95	65	75	**78.3333**
5	107	108	97	**104**	628	570	386	**528**	110	76	90	**92**
6	117	112	102	**110.333**	643	577	392	**537.333**	145	88	103	**112**
7	122	116	107	**115**	655	584	397	**545.333**	152	103	117	**124**
8	126	120	111	**119**	665	591	401	**552.333**	204	116	131	**150.333**
9	130	123	114	**122.333**	675	594	406	**558.333**	262	148	148	**186**
10	134	127	118	**126.333**	682	602	410	**564.667**	262	162	167	**197**
11	137	130	121	**129.333**	689	591	414	**564.667**	263	175	183	**207**
12	140	134	125	**133**	696	594	417	**569**	264	180	184	**209.333**
13	144	137	128	**136.333**	703	597	420	**573.333**	281	187	199	**222.333**
14	147	140	131	**139.333**	707	601	422	**576.667**	290	200	219	**236.333**
15	150	143	134	**142.333**	714	605	424	**581**	296	215	246	**252.333**

Time (in minutes)	***Photo-resistance (kΩ)***		
	At room temperature 31°C	***In Ice cold water at 9°C***	***In Hot water at 75°C***
0	54.6667	473.667	17.3333
1	73	487.667	37
2	84.3333	496.333	51
3	93.3333	506	66
4	99.6667	517	78.3333
5	104	528	92
6	110.333	537.333	112
7	115	545.333	124
8	119	552.333	150.333
9	122.333	558.333	186
10	126.333	564.667	197
11	129.333	564.667	207
12	133	569	209.333
13	136.333	573.333	222.333
14	139.333	576.667	236.333
15	142.333	581	252.333

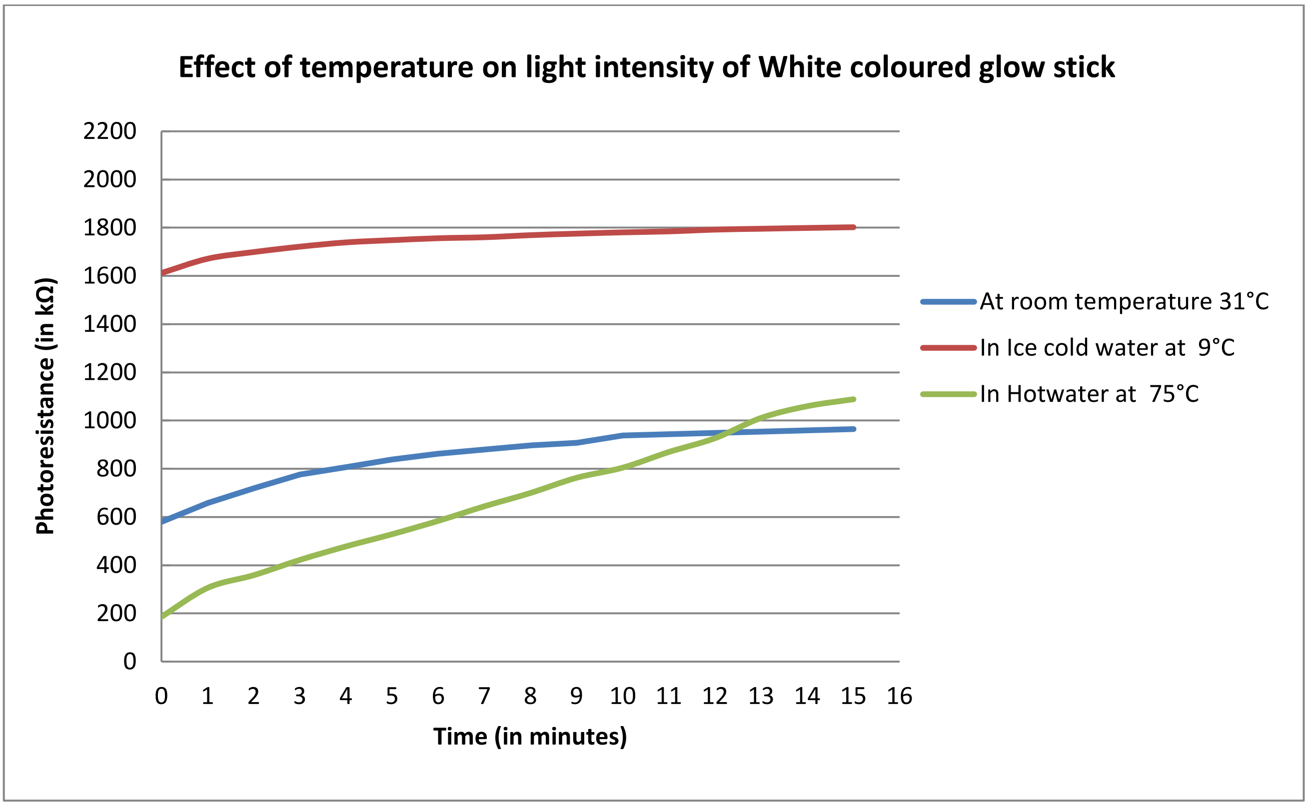
Table 6 : Effect of temperature on light intensity of ORANGE coloured glow stick

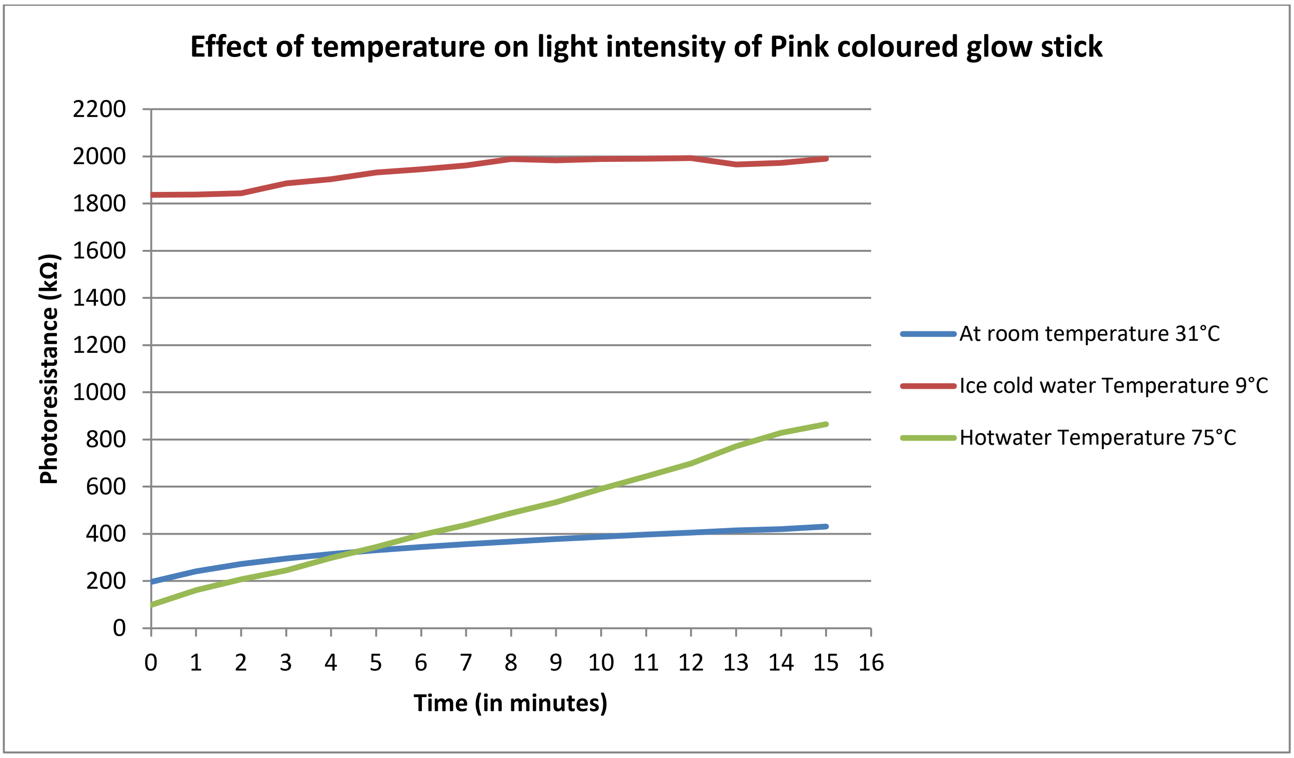
Time (in minutes)	Photo-resistance (kΩ)											
	At room temperature 31°C				In Ice cold water at 9°C				In Hot water at 75°C			
	Trial 1	Trial 2	Trial 3	AVG	Trial 1	Trial 2	Trial 3	AVG	Trial 1	Trial 2	Trial 3	AVG
0	94	114	56	88	502	1101	569	724	19	24	19	20.6667
1	106	137	80	107.667	547	1189	599	768.333	65	61	38	54.6667
2	114	152	93	119.667	552	1210	616	787	89	78	49	72
3	122	165	102	129.667	555	1240	635	810	121	94	60	91.6667
4	127	176	109	137.333	557	1270	665	830.667	140	125	75	113.333
5	132	185	115	144	565	1302	694	853.667	162	153	87	134
6	137	193	119	149.667	581	1329	720	876.667	170	179	127	158.667
7	141	200	123	154.667	591	1351	743	895	187	208	161	185.333
8	144	206	127	159	596	1369	761	908.667	208	231	193	210.667
9	148	213	131	164	597	1374	773	914.667	293	259	213	255
10	151	218	134	167.667	601	1387	786	924.667	325	290	226	280.333
11	155	224	137	172	605	1395	795	931.667	358	321	268	315.667
12	159	230	140	176.333	609	1403	804	938.667	385	349	296	343.333
13	162	236	143	180.333	611	1406	812	943	425	387	348	386.667
14	164	240	146	183.333	615	1410	819	948	425	404	351	393.333
15	168	246	149	187.667	617	1414	825	952	456	440	394	430

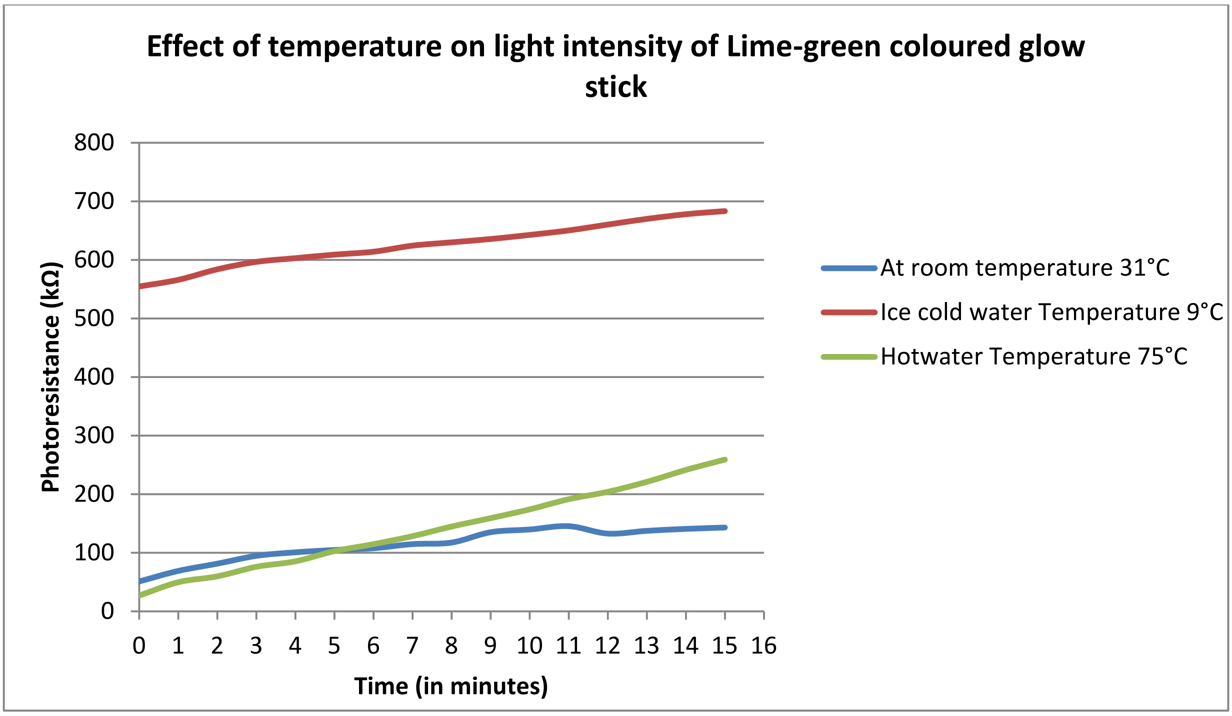
Time (in minutes)	***Photo-resistance (kΩ)***		
	At room temperature 31°C	***In Ice cold water at 9°C***	***In Hot water at 75°C***
0	88	724	20.6667
1	107.667	768.333	54.6667
2	119.667	787	72
3	129.667	810	91.6667
4	137.333	830.667	113.333
5	144	853.667	134
6	149.667	876.667	158.667
7	154.667	895	185.333
8	159	908.667	210.667
9	164	914.667	255
10	167.667	924.667	280.333
11	172	931.667	315.667
12	176.333	938.667	343.333
13	180.333	943	386.667
14	183.333	948	393.333
15	187.667	952	430

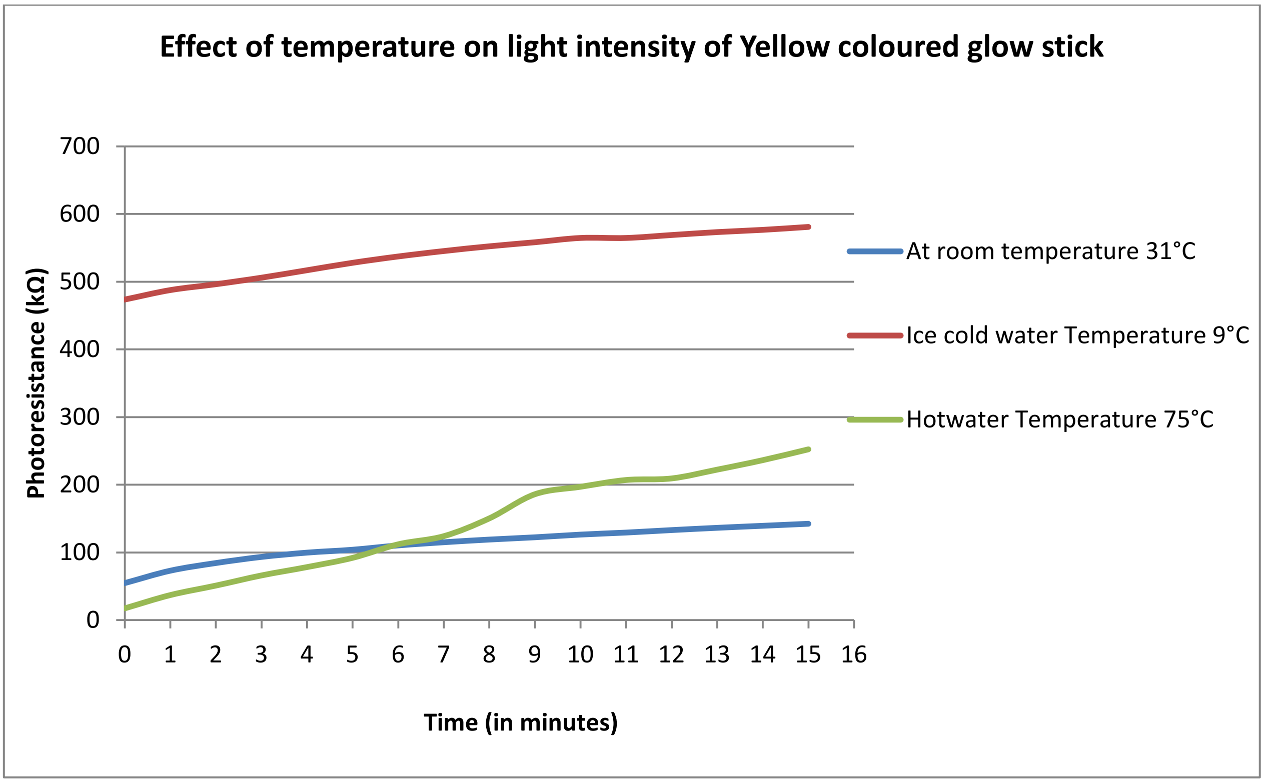
Graphical Representation

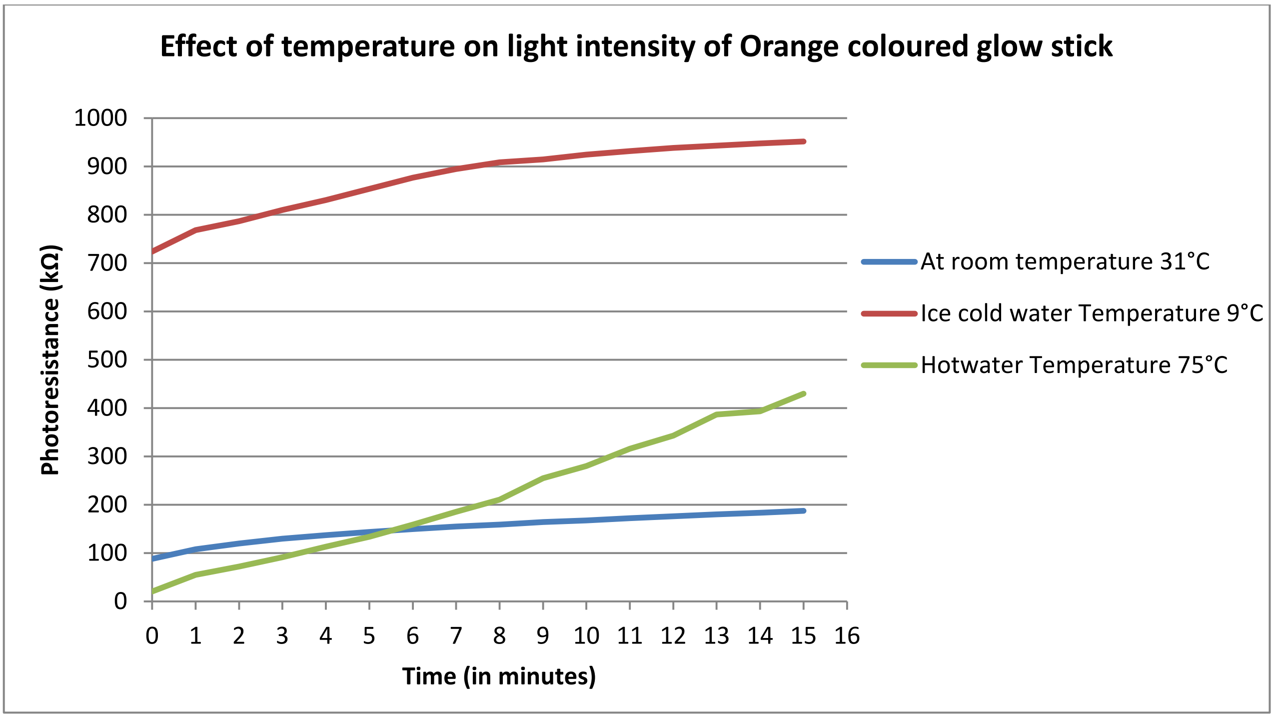
THE EFFECT OF TEMPERATURE ON LIGHT INTENSITY OF DIFFERENT COLOURED GLOW STICKS



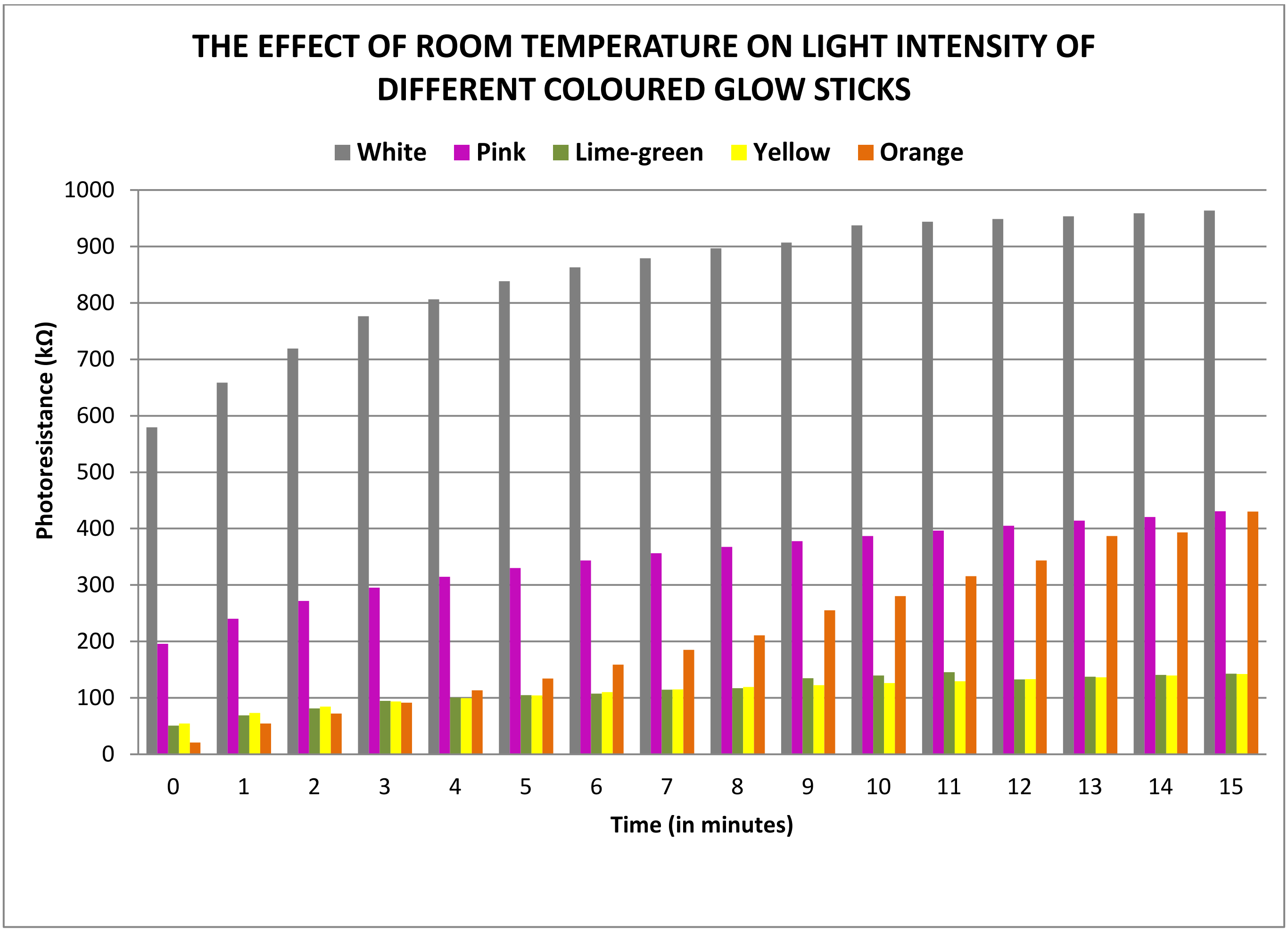



Effect of temperature on light intensity of Lime-green coloured glow stick
Photoresistance (kΩ)
800
700
600
500
400
300
200
100
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Time (in minutes)
At room temperature 31°C
Ice cold water Temperature 9°C
Hotwater Temperature 75°C

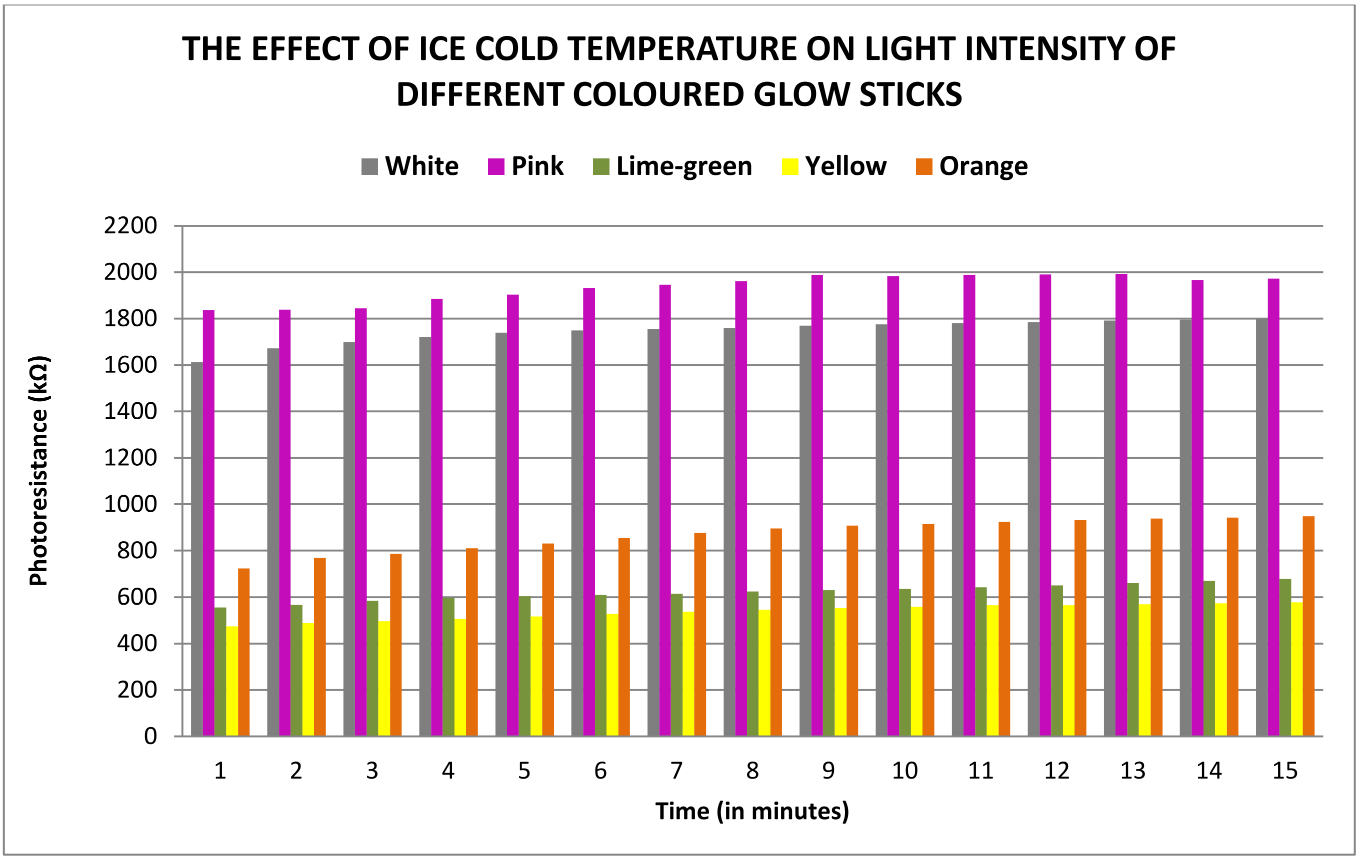

Effect of temperature on light intensity of Yellow coloured glow stick
Photoresistance (kΩ)
700
600
500
400
300
200
100
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Time (in minutes)
At room temperature 31°C
Ice cold water Temperature 9°C
Hotwater Temperature 75°C

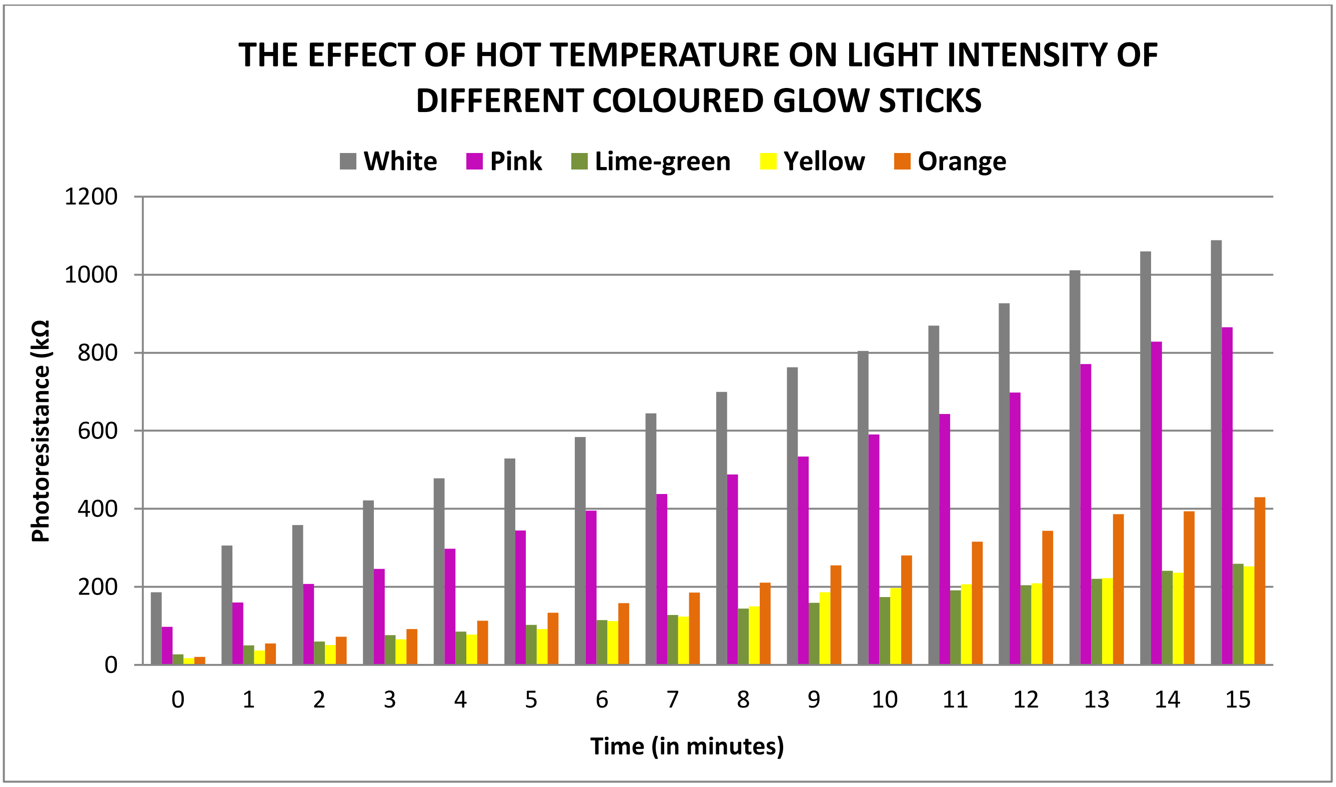


Effect of temperature on light intensity of Orange coloured glow stick
Photoresistance (kΩ)
1000
900
800
700
600
500
400
300
200
100
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Time (in minutes)
At room temperature 31°C
Ice cold water Temperature 9°C
Hotwater Temperature 75°C



THE EFFECT OF ROOM TEMPERATURE ON LIGHT INTENSITY OF DIFFERENT COLOURED GLOW STICKS
White
Pink
Lime-green
Yellow
Orange
Photoresistance (kΩ)
1000
900
800
700
600
500
400
300
200
100
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (in minutes)


THE EFFECT OF ICE COLD TEMPERATURE ON LIGHT INTENSITY OF DIFFERENT COLOURED GLOW STICKS
White
Pink
Lime-green
Yellow
Orange
Photoresistance (kΩ)
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (in minutes)


THE EFFECT OF HOT TEMPERATURE ON LIGHT INTENSITY OF DIFFERENT COLOURED GLOW STICKS
White
Pink
Lime-green
Yellow
Orange
Photoresistance (kΩ
1200
1000
800
600
400
200
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (in minutes)

RESULTS AND DISCUSSION

- In the baseline test, the resistance of photo-resistor with the closed lid was above 2000kΩ. I used this as confirmation test value for knowing the baseline of the photo-resistor I had taken.

A. Time Vs Light intensity

- By plotting the data, I got a *more or less a straight line, away from x-axis* which indicates the photo-resistance is directly proportional to the time.
- Increasing photo-resistance implies decreasing light intensity. Hence, ***light intensity decays over time.***

B. Colour Vs Light intensity

- Comparing all, ***Yellow has more light intensity in all the temperature.***
- *Increasing order of light intensity at room temperature 21°C:*

  White < Pink < Orange < Lime-green < Yellow

- *Increasing order of light intensity in ice cold water at 9°C :*

  Pink < White< Orange < Lime-green < Yellow

- *Increasing order of light intensity in hot water at 75°C:*

  White < Pink < Orange < Lime-green < Yellow

C. Temperature Vs Light intensity

- I observed the greater increase in the photo-resistance in ice cold water from that of hot and room temperatures, for all the colours both at initial and final time point.
- Comparing hot and room temperature, resistance was initially low at hot which means high light intensity but gradually increased after 15minutes, whereas at room temperature, resistance maintains an approximate value. It may be due to the loss of heat. From this, I formulated the fact that ***increasing temperature actually increases light intensity*** unless and until the heat is maintained.
- The range of multimeter I had was 2000kΩ. For the, I have considered display readings 1as 2000kΩ and plotted my data.
- Some glow sticks may have manufacturing defect, so I have taken three trials for promising results.

CONCLUSION

My hypothesis, "Cold temperature increases the Light intensity of glow sticks" has not been proved. I found that increasing temperature increases the light intensity.

FUTURE ENHANCEMENT

- I want to continue my experiment with the apt range of multimeter (>2000kΩ).
- I should update my setup so that the temperature drop/rise can also be noted along with the resistance so as to determine the particular point of temperature at which the resistances increase/decrease.
- Furthermore, I want to compare among different hot temperatures ranging from 50°C to 100°C for colours other than the ones I have used.

APPLICATION

- The science behind chemiluminescence could be possibly utilized for future light generating mechanisms.
- Chemiluminescence is a non-radioactive, chemical reaction which produces a white light. It finds its application in *chemiluminescent western blotting*, where chemiluminescence occurs when a chemiluminescent substrate attached to an antibody bound to the target protein undergoes an enzyme-based reaction.
- Chemiluminescence is more sensitive than colorimetric protein detection because the antibody targets the protein specifically and the enzyme amplifies the light signal.

Since chemiluminescent molecules produce so many photons of light, with the right types of image capture technology, *chemiluminescence can be used to detect proteins that are expressed at low levels.* Since chemiluminescent light is generated internally, protein sample won't be damaged, and can be re-used.

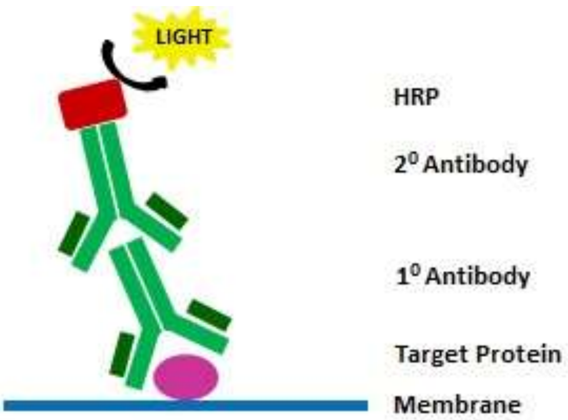


Figure 1- Chemiluminescence western blot
Primary antibody (1°) binds to a target protein on the membrane. The membrane is then incubated with a chemiluminescence substrate e.g. HRP. An enzymatic reaction occurs producing light which is detected by a CCD camera.

ACKNOWLEDGEMENT

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