

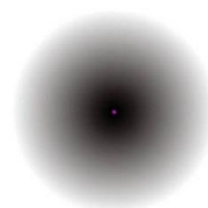
Emission Spectrum of Hydrogen and Neon

Introduction

Developments in the atomic theory have expanded the scope of research for scientist. From Niels Bohr's orbital shell model of the atom came Max Planck and Albert Einstein who shaped the face of Quantum Physics. Most notably came the discovery by the Father of the quantum theory, Max Planck, that light was quantised, meaning that they came in packets. His work (Planck, 1900) deviated from Classical Physics as it brought forth the fact that energy wasn't continuous, rather came in discrete units. Einstein's work in 1905 on the behaviour of light saw the uprising of the theory particle-duality of light. The proposed idea stated that light had features of a wave, but also a particle. This theory was supported by evidence from Thomas Young's double slit experiment and the work of Max Planck.

Thomas Young's double slit experiment presented solidifying evidence that light acted as a wave. In the early 19th Century, Physicist Thomas Young allowed light to propagate through two wavelength size slits and thus observed an interesting phenomena. Light acted like waves in a pond and resulted in superposition. Two forms of superposition, constructive interference (two crests meet) and destructive interference (one crest meets another trough) were evident in his experiment. In constructive interference, the waves combine and increase in size, whereas in destructive interference, the waves cancel each other out. Henceforth, Young concluded that light had properties of a wave.

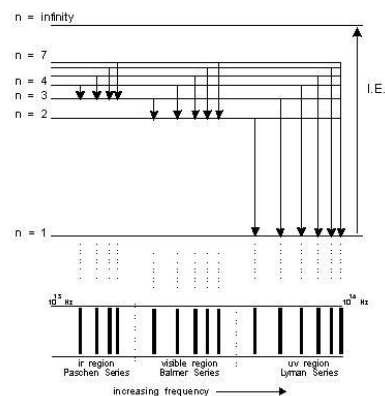
The Modern quantum theory of the atom is constituted by discrete energy levels which include sub energy levels. These are discrete energy levels in which an electron remains. In order for an electron to 'jump' energy levels, it must absorb a specific amount of energy from a photon, or emit a specific amount of energy. The current model is also characterised by protons and neutrons in the nucleus held together due to mesons. Protons and neutrons are each made up of quarks which are held together by gluons. There is indeed greater amounts of subatomic particles which constitute quarks and so forth. This theory additionally takes into consideration Heisenberg's Uncertainty Principle and thus, as we can never know the position and momentum of an electron, we work with probability densities. This essentially determines the probability that an electron will occupy an area, hence, giving it a greater density as opposed to a lower probability. These constituents of the atom allow scientists to explain certain phenomena with greater accuracy.



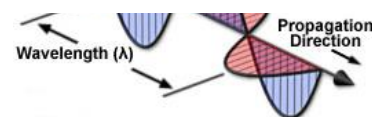
Hydrogen Electron Cloud:
<http://subatomic soup.wordpress.com/tag/quantum-physics/>

With the fact that the energy of the electron is associated with that of the orbital, the electron configuration of the elements to be used in this experiment should be determined. Within the atom, there are sub-energy levels in the form of S, P, D and F orbitals. The electron configuration of Hydrogen is $1s^1$ and the electron configuration of Neon is $1s^2 2s^2 2p^6$. The following electron configurations are for the ground state with the lowest energy. As an atom is excited, the electron configuration is deviated. Generally, when valence electrons (electrons in the outer most shell) are excited, electromagnetic radiation such as infrared, visible light and ultra violet will be emitted. Conversely, electrons that aren't in the outer most shell have the propensity to emit x-rays when excited. The wavelengths of the electromagnetic spectrum that are emitted make up the emission spectrum.

As an atom is excited, the electron is placed in a higher energy state as it absorbs a discrete amount of energy (a photon with a certain amount of energy). It is important to note that the electron will only 'jump' energy levels if the exact amount of energy is absorbed in correlation with a particular energy level. As a result of the electron being in a higher energy state, it essentially moves to a lower energy state or the ground state. This reaches stability in the atom. The way the electron moves to a lower energy state is through the emission of a photon of corresponding energy to do so. This is evident as the conservation of energy states energy cannot be created or destroyed, rather, can change forms. In this case, the energy is lost from the electron in the form of electromagnetic radiation. The energy of the photon that is emitted is categorised into the Paschen, Balmer and Lyman series. The Paschen series constitutes the transitions of electrons from $n \geq 4$ to $n = 3$. These are wavelengths in the infrared (wavelengths 1mm-750nm). The Balmer series constitutes the transitions of electrons from $n \geq 3$ to $n = 2$. These wavelengths are in the visible light spectrum (wavelengths 750nm- 450nm). The Lyman series constitutes the transitions of electrons from $n \geq 2$ to $n = 1$. These are wavelengths in the ultra-violet (wavelengths 400nm-10nm). X rays may also be emitted (wavelengths 10nm and less). It is important to note that humans can only see in the visible spectrum, thus, wavelengths in the ultraviolet and infrared will be unable to be seen and hence, calculated.



Hydrogen's Formation of Atomic Spectra:
<http://www.avogadro.co.uk/light/bohr/spectra.htm>



James Clerk Maxwell, inspired by Faraday's work on electromagnetism, in 1865 proposed his theory on the electromagnetic property of light. He stated that if a changing magnetic field can create an electric field, then so too can a changing electric field create a magnetic field. As a result, the changing electric and magnetic fields will create each other and this would occur at 'c,' the speed of light ($2.998 \times 10^8 \text{ms}^{-1}$). This formed the basis that light is an electromagnetic wave. The magnetic and electric fields are both perpendicular to each other, while the direction of propagation is perpendicular to both the fields. In reference to the defining properties of light, the wavelength (nm) is the distance between two successive crests of a wave. The frequency (Hz) is number of crests that pass a point in a given second.

Electromagnetic Wave:
<http://www.olympusmicro.com/primer/lightandcolor/electromagintro.html>

In 1752, Scottish Physicist Thomas Melville presented that the emission spectra of different elements were different. The emission spectrum is essentially the electromagnetic radiation that a substance emits. Atomic emission spectra is specific to the electromagnetic radiation that certain elements emit. The emission spectrum of an element is seen as their 'fingerprint' and is unique to every element. With reference to the following experiment, equipment such as a transformer, discharge tubes and a diffraction grating are used in order to observe the emission spectrum of diatomic hydrogen and monatomic neon, as well as, calculating the relationship between certain properties of light. Hydrogen, in gaseous form is diatomic due to the fact that in order to have their valence electrons 'full,' and to reach stability through a covalent bond. Neon, however, is monatomic in its gaseous state due to the fact that it is a noble gas, thus, is unreactive and already has eight valence electrons and is hence, already stable.

In order for an atomic emission spectrum to be observed, the particle must be excited. Atoms can be excited by heating the gas to a high temperature or passing an electric current through the gas. In this experiment, the excitation of hydrogen and neon atoms will be electrically induced through high voltage. Voltage is the change in potential energy per charge. Conventionally, an electric field is a vector and when a charged particle travels in the opposing direction to the electric field vector, the voltage increases as the potential energy increases. This will require a transformer which transforms a low voltage source into a high voltage source. The voltage produced by a Ruhmkorff coil is approximately 23kV for a 4mm gap. The presence of a gap results in an arc discharge between two charged metals. By increasing the spark gap, the voltage is increased and by decreasing the spark gap, the voltage decreases. The induction coil is also composed of a capacitor which is an electrical component storing energy in the form of an electrostatic field. This capacitor increases the efficiency of the coil.

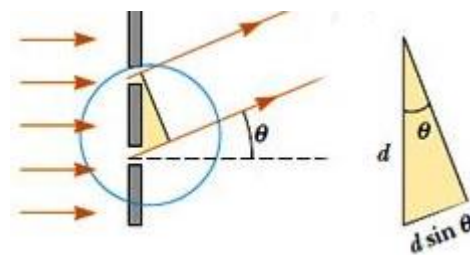
The discharge tube is a gas filled tube, including one to several gases which is sealed and at lower pressure than 1

atmospheric pressure. The glass tube is comprised of a cathode and anode, as well as parallel plates which require a high voltage in order for the electrons to flow through. This is due to the fact that the electrons will only flow once the electric field strength is greater than the electronegativity. As a result, the electrons flow towards the anode.

The diffraction grating is a pivotal part in breaking the light emitted by the atoms into their constituent wavelengths, thus, projecting the emission spectrum of a particular element onto a surface. Diffraction is when light changes direction after passing through a barrier or narrow aperture. Diffraction grating can be set into two categories, linear and circular. A diffraction grating in particular has several lines, ranging from 1,000 to even 7,000 lines per mm. The diffraction grating used in the experiment will be a 13,500 lines/inch linear diffraction grating. It is, in a sense, a broader application and exaggerated reproduction of Thomas Young's double slit experiment. As a result, certain phenomena such as changes in intensities and dark fringes should be observed. In using Huygens's principle that every point on a wavefront acts like a new source, it is evident that each slit is a new source and thus, the waves spread out from there interacting with each other. This interacting results in waves being superimposed. In regards to diffraction grating, the slits must be the same distance as the wavelength, as if the slit is too large, the wave passes right through and conversely, if too small, the wave would reflect back. In trying to find out the wavelength of light, the following equation which shows the relationship between the angle of the light, distance of slit and period to the wavelength:

$$\lambda = \frac{d \sin \theta}{n}$$

The above equation indicates that the wavelength is proportional to the distance of the slit and angle of light. It also indicates that the wavelength is inversely proportional to the period. The derivation of the equation is taken from two waves out of slits and the relationship between the two. This relationship shows that if $d \sin \theta$ is one complete wavelength, then the two crests are in sync and thus, results in constructive interference. Additionally, if $d \sin \theta = \frac{\lambda}{2}$, the crest of one wave should meet the trough of another, resulting in the waves experiencing destructive interference.



Derivation of $\lambda = \frac{d \sin \theta}{n}$ equation:
<http://www.physicshelp.com/149>

Throughout Bohr's study of Hydrogen's emission spectra, he postulated that when an electron falls from a higher energy state to a lower one, the energy emitted is given by:

$$\Delta E = hf = \frac{hc}{\lambda}$$

The equation essentially states that the energy released ($E_2 - E_1$) is proportional to the frequency of light. The energy released is inversely proportional to the wavelength. The above equation also defines the discontinuous nature of energy and that the wavelength can be found by knowing the energy jump. This will be used in order to quantify the energy released, linking it to an energy level jump through the Rydberg equation. The Rydberg equation describes the spectral lines for hydrogen. In order to find the period jump, the Rydberg constant is used. Where R_H is the Rydberg Constant (1.907×10^7), n_f and n_i are the energy level jumps.

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

To then find the relationship between frequency and wavelength, we know that the speed of light is equal to the wavelength multiplied by the frequency, thus, rearranging the equation provides us with the information to find the frequency:

$$f = \frac{c}{\lambda}$$

The above equation shows that the frequency of light and the wavelength of light are inversely proportional and by substituting the constant c and the given wavelength, the frequency can be found.

There are a myriad of practical applications of this experiment in the world. Neon lights are widely used in regards to the discharge tube. Neon lights are essentially a neon gas discharge tube and involves applying a high voltage of some thousands of volts to light up. Neon lighting is has been widely used in terms of business and especially in high commercial centres. The neon lights emit a dramatic red colour which was popular for advertising. Now, these neon lights and panels are used in some plasma displays. In fact, the plasma TV is built upon this phenomena. The picture is displayed as Xenon and Neon gas atoms, as well as electrons collide, thus, releasing energy. This energy causes excitations, hence, the electrons jump to a higher energy state and as the electron drops to a lower energy state, it emits a photon. This has had a dramatic impact on the television industry and advancements in technology.

Furthermore, the emission spectrum of certain chemicals, especially water are used in space exploration to find certain chemicals on other planets. For example, the emission spectrum of water is used to try and find the corresponding emission spectrum in other areas in the universe. Spectroscopy is especially used to the fact that the emission/absorption spectrum is akin to a fingerprint for an element, molecule or compound. NASA, in deep impact space missions, use infrared spectrometers to see the portions of infrared energy emitted by certain planets and comets. This data is analysed and compared to known emission/absorption spectra to collect information and undertake more research into the area. The emission spectrum is also increasingly useful in regards to finding the ionisation energy for a certain element. This is essentially the energy required to lose an electron and is thus, useful to scientists during research and work. These are also an important part of understanding why certain atoms make covalent or ionic bonds which play importance in any chemical reaction.

Finally, the aurora borealis, or more commonly known as the Northern Lights are a phenomena which uses the same phenomena as the discharge tube to emit light. Essentially, the poles are the only areas where plasma comes into contact with Earth's atmosphere and isn't deflected by Earth's magnetic field. When the atoms in Earth's atmosphere such as Nitrogen, Oxygen and Helium are struck by the plasma, it excites the atoms. As a result, the electrons jump to higher energy levels and as they drop to a lower energy state, due to the conservation of energy, a photon of the energy difference between the two levels n_f and n_i are emitted. The colours vary depending on the quantity and type of gas present in the atmosphere. Oxygen atoms emit green, yellow or red light, while nitrogen atoms emit high frequency blue light. The mixture of all of these colour cause the aurora borealis.

Aim:

To determine how the energy jumps of the electron between orbitals (energy released) affects the wavelength and frequency of the corresponding photon in Hydrogen and Neon atoms

Hypothesis:

As the energy jump of the electron is increased (energy released), the wavelength of the photon decreases. As the energy jump of the electron is increased (energy released), the frequency of the photon increases

Variables:

Independent Variable:

The energy released (the electron jump) from a photon. The amount of energy released by photon will be changed by changing the element used, in this case I will be using two gas discharge tubes. One Hydrogen and one Neon discharge tube.

Dependent Variable:

The dependent variable is the wavelength of the photon. This will be calculated using:

$$\lambda = \frac{d \sin \theta}{n}$$

The dependent variable is also the frequency of the photon. This will be calculated using:

$$f = \frac{c}{\lambda}$$

Controlled Variables:

| Variable | How could it affect your experiment? | How will it be controlled? |
|---|--|--|
| Voltage used in the power pack | It would affect the overall voltage produced by the induction coil and thus, affect the relative jump of the electrons from the hydrogen and neon discharge tubes | This will be controlled by using the a 6V power pack for both the hydrogen and neon gas discharge tube |
| Voltage used in the Induction Coil | The high voltage source needs to remain constant with both the neon and hydrogen gas discharge tubes as this will too affect the relative jump of the electrons from the hydrogen and neon discharge tubes | This will be controlled by using the same 12V power pack as well as the same Ruhmkorff induction coil for both the neon and hydrogen discharge tubes |
| The length of the wire alligator clips | Energy may be lost as the electrons flow through, thus, if using different lengths of alligator clips, the consistency and energy jumps of the electrons would differ from the gases. | By using the same length wire of the alligator clips |
| The cross-sectional area of the wires used in the alligator clips | The cross-sectional area affects the resistance of the wire. If there is a greater cross-sectional area, there is thus, lower resistance. This can create an unfair experiment between hydrogen and neon. | By using the wires in the alligator clips of the same cross-sectional area |

| | | |
|--|---|---|
| The same material used in the wires of the alligator clips | The resistivity must remain constant to produce a fair experiment. If there is different materials used, the resistivity will differ between different alligator clips, and thus, create a disparity between the results of the hydrogen and neon emission spectrum and intensities of light. | By using alligator clips of the same material, it will have the same resistivity. |
| The quantity of light in the environment | If there is a large quantity of light in the area, constructive and destructive superposition would occur with the photons, thus, resulting in a deviated result of 'n', as well as the wavelengths of light. | It will be attempted to partake the experiment with extremely dim light to no light to maximise the accuracy of the emission spectra of hydrogen and neon. |
| The purity of the gas in the discharge tube | If the gas discharge tubes are not comprised of purely hydrogen or purely neon, the experiment would fail as the emission spectrum would show numerous false wavelengths of a particular gas, as it is from another gas. | By using gas discharge tubes with only one type of gas each. In this case, it would be one purely diatomic hydrogen gas discharge tube and one elemental neon gas discharge tube. |
| The pressure in the gas discharge tube | The amount of pressure may affect the environment of the gas and deviate the results of the experiment. | By ensuring there is constant pressure with both the hydrogen and neon tubes |
| The same material on the anode and cathode on the gas discharge tube | This is also a matter of resistivity, thus, keeping a constant material will ensure a constant resistivity amongst both discharge tubes. | By ensuring that the material of the cathode and anode are constant amongst both discharge tubes |
| The quantity of a certain gas in the discharge tube | This affects the current, which ultimately affect the wavelengths which will be observed and calculated | By ensuring the quantity of gas in each discharge tube is constant |

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| The size of the discharge tube | The intensity of certain wavelengths will be distorted if there is a deviation between the sizes of both the discharge tubes. This will thus, affect the calculations and result in an unfair experiment. | By ensuring that the length of both discharge tubes are 26cm and the cross sectional area on each point is constant amongst both discharge tubes. |
| The distance between the gas discharge tube and the diffraction grating | This must be constant between each gas to ensure that calculations are the same, with only the one factor changing. | By ruling out the same distance between the gas discharge tube and the diffraction grating. |
| The distance between the diffraction grating and the flat surface perpendicular to the table | This also must be kept the same to ensure that calculations are also made with ease. | The distance between the diffraction grating and the flat surface will be one metre for both the test subjects. |
| The slit size on the diffraction grating | This is pivotal as 'd' is dependent on the slit distance in metres | The diffraction grating I have is 13,500 lines/inch. Thus, by using only this diffraction grating for both discharge tubes, the experiment will be consistent |
| The type of diffraction grating | The type of diffraction grating and effect certain phenomena which is observed. By having the same type of diffraction grating, it is ensured that that the results will be constant | The diffraction grating which will be used is defined as 'Diffraction Grating Roll Sheet Double Axis 13,500 lines/inch laser spectrometer' and will be used for both tubes |
| The material of the diffraction grating | If the material of the diffraction grating is different, then the structure of the diffraction grating may be different. For example, some diffraction gratings are of a prism aperture which would distort the dynamic of the experiment at hand. | By using the same diffraction grating for both discharge tubes, It will ensure that it will be the same material, have the same refractive index and ultimately, the same effect. |

| | | |
|---|---|---|
| The same stand for the gas discharge tubes | This stand must be the same and elevated to the same height to ensure that all factors mentioned above correlate with this, especially the diffraction grating position. | By using the same stand and the gas discharge tubes elevated to the same height. |
| The temperature (average kinetic energy) of the surroundings | This could already affect the movement and jumps of the electron throughout orbitals, thus, it is essential to keep the same kinetic energy of the surroundings | Doing the test in the same place on the same day, the kinetic energy of the surroundings should stay constant. |
| The atmospheric pressure of the surroundings | This could also affect the pressure of the gases inside the discharge tube and thus, affect the results of the experiment | Doing the test in the same place on the same day, the atmospheric pressure should stay constant. |
| The colour of the flat surface perpendicular to the table | This may distort the colours that are observed and calculated. | By using a completely white or black colour for the material used as the flat surface, it will ensure greater contrast and remain constant between the test |
| The angle of the diffraction grating | May effect the intensity of the wavelengths which could also thus, deviate the observations that are essentially made by me. | Keeping it perpendicular to the table/flat surface to ensure the colour is as intense as it could be with both the test subjects |
| The positing of the diffraction grating in relation to the gas discharge tube | If the positioning of the diffraction grating is deviated in relation to the gas discharge tube, certain factors such as intensity of the light and the projection of the emission spectrum will deviate and hence, the calculations will also be differed which results in an unfair experiment. | By placing the diffraction grating in the same position for both the hydrogen and neon discharge tubes. |

Equipment:

- 1 x 6V Power Pack
- 1 x High Voltage Power Source (Ruhmkorff Induction Coil)
- 4 x Connection wires (blue, yellow, red and black)
- 4 x Alligator Clips
- 1 x Hydrogen Discharge Tube
- 1 x Neon Discharge Tube
- 1 x 13,500 lines/inch Diffraction Grating
- 1 x Ruler
- 1 x Calculator
- 1 x Paper
- 1 x Wide Table
- 1 x Light Sheet of Fabric
- 1 x Wooden Discharge tube stand
- 1 x Diffraction grating stand
- 1 x Power point
- 1 x Rubber gloves

Method:

1. Set up a light sheet of fabric perpendicular to the wide table near a power point
2. Place a line of paper, using a ruler at each 10cm interval from a centre point on the light sheet of fabric
3. Rule a 1.05 metre distance, flush with the table, from the light sheet of fabric and mark it with a pen
4. Connect the power pack to the induction coil using the black and red connecting wires to connect the anode of the power pack to the anode of the discharge tube, as well as the corresponding cathodes
5. Connect the induction coil to the Hydrogen Discharge Tube using the blue and yellow connecting wires and alligator clips. The polarity in this case does not matter.
6. Place the Hydrogen Discharge tube on a wooden stand 5cm away from the light sheet of fabric
7. Place the diffraction grating on the diffraction grating stand directly on the marked distance 1.05 metre away from the fabric and 1m away from the discharge tube
8. Connect the plug of the power pack into the power point
9. Open the switch on the power pack and open the switch on the induction coil
10. Once Hydrogen's emission spectrum is visible, whilst wearing rubber gloves, mark the first colour and measure its distance away from the centre

11. Close the switch on the Induction Coil and the power pack
12. Measure the distance of the colour away from the centre using a ruler and mark it on the light sheet of fabric
13. Use the given distance to find $\sin\theta$ and substitute the necessary values to find the wavelength for:

$$\lambda = \frac{d \sin\theta}{n}$$

14. Record the result in the logbook
15. Repeat steps 9-14 for every colour observed on the emission spectrum
16. Using the Rydberg Equation, note the correlated electron jump on the Balmer Series
17. Calculate the quantity of energy released that each wavelength pertains by substituting the value of the given wavelengths of hydrogen using:

$$\Delta E = \frac{hc}{\lambda}$$

18. Record results in the logbook
19. Calculate the frequency of the emitted photons by substituting the necessary values using:

$$f = \frac{c}{\lambda}$$

20. Record the results in the logbook
21. Record any observations made in the logbook
22. Repeat steps 9-21 six times for reliability and calculate the average of the results
23. Repeat steps 9-22 using the Neon Discharge Tube

Risk Assessment:

| Identify | Control | Assess |
|--|--|----------------------------------|
| The hydrogen and neon discharge tubes are very fragile, made of glass and if dropped, the glass may shatter resulting in skin lacerations which creates an open wound and possible entrance points for pathogens | By holding the gas discharge tubes with two hands, as well as using a discharge tube stand in order to keep stability of the discharge tubes | Low Risk if controls are applied |
| The 12 Volt Power pack may cause electrocution due to broken wires or wires that are not insulated | Ensuring that the connecting wires are insulated and have a non-conductive layer surrounding the conductive wire | Low Risk if controls are applied |
| If electrodes connect or disconnect throughout the running of electricity, sparks and an explosion could be produced, causing burns to the skin and skin irritation | Don't make contact with the electrodes throughout the process. If a modification is needed, the motor and running of electricity must be off | Low Risk if controls are applied |

| | | |
|--|--|--------------------------------------|
| The induction coil (producing up to 23kV) used in areas of a moist atmosphere causes a greater risk of explosion and electrocution in regards to the induction coil | Ensure that the use of the induction coil is in a dry environment | Low Risk if controls are applied |
| The induction coil, once attached to the hydrogen and neon discharge tube, emits low energy X- rays which may cause mutations to human cells if exposure to the radiation is long | By turning the induction coil off every 30 seconds that the induction coil is in use, ensures that exposure the low energy X rays are minor and negligible to have effects on humans | Medium Risk if controls are applied |
| If using two hands and the table is very busy with the equipment not spaced out, it can result in a short circuit which results in electrocution | By leaving one hand behind my back and having a wide table, with all of the equipment spaced out, it ensures that the chances of a short circuit are quite minute | Low risk if all controls are applied |
| Handling the discharge tube while it is in operation causes greater and direct exposure to Electromagnetic Radiation including X-Rays which can cause damage to skin and mutation to cells | Always turning off the induction coil and power pack whilst needing to handle the discharge tube. Also, by standing 2 metres away from the discharge tube while it is on is required. | Low Risk if all controls are applied |
| The diffraction grating has sharp edges which may cause cuts to the skin and lacerations which provide and open pathway for pathogens to enter, thus, causing potential disease | By wearing blue disposable gloves, it decreases the event that a cut or slicing of the skin may take place | Low Risk if all controls are applied |
| If the hydrogen discharge tube breaks and inhalation of the hydrogen gas occurs, dizziness and possible unconsciousness may occur | Keeping the hydrogen discharge tube away from any edges, keeping it on a stand and in the case that it does break, closing the switch and either leaving the room and keeping your face away from the discharge tube | Low Risk if all controls are applied |

| | | |
|--|--|--|
| <p>The arc discharge on the top of the induction coil provides approximately 2-3 amps which, if made contact with human skin, can cause severe burns and electrocution</p> | <p>By wearing rubber gloves, always having one arm behind my back when operating it and always turning off the power when needing to modify anything, the risk is reduced</p> | <p>Medium risk if all controls are applied</p> |
| <p>The wire breaking due to a breach of the power capacity may cause shock</p> | <p>Ensuring the power pack and the induction coil has a fuse and keep distance whilst the electrical components are working</p> | <p>Medium risk if all controls are applied</p> |
| <p>The dark room can lead to tripping over equipment or any objects on the floor, causing possible fractures and abrasions</p> | <p>By always standing next to the light switch and completing the experiment in an open room where there are no hazardous objects to trip over</p> | <p>Low risk if all controls are applied</p> |
| <p>The discharge tube, when on, can emit UV rays which will otherwise make contact to skin due to low levels of melanin, thus, resulting in possible mutations in skin cells</p> | <p>Wearing sunscreen ensures that the UV rays are reflected off of skin. Additionally, by wearing plenty of clothing, there is a reduced chance of being affected by the UV rays</p> | <p>Low risk if all controls are applied</p> |

Diagrams:

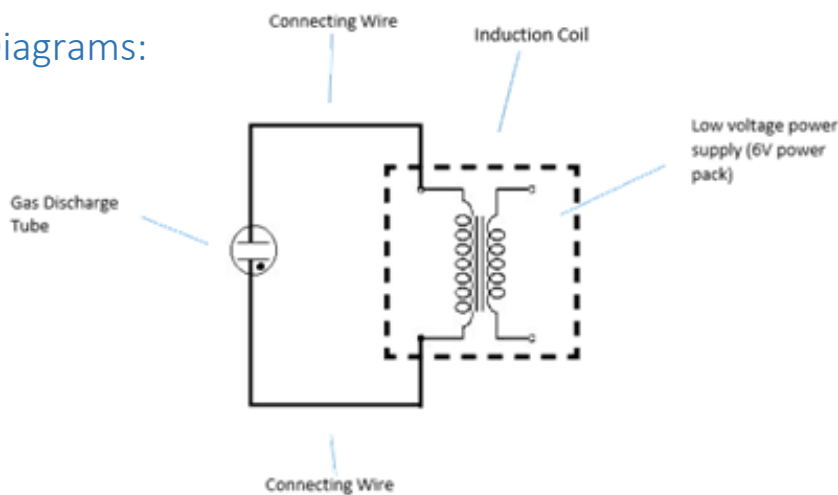


Diagram 1: Full Circuit

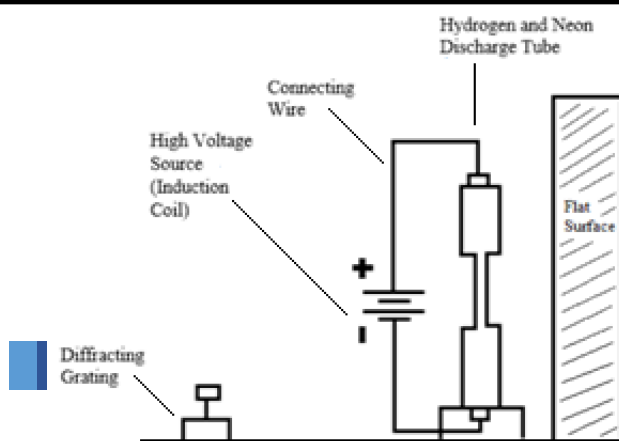


Diagram 2: Side depiction of the Positioning of the Equipment

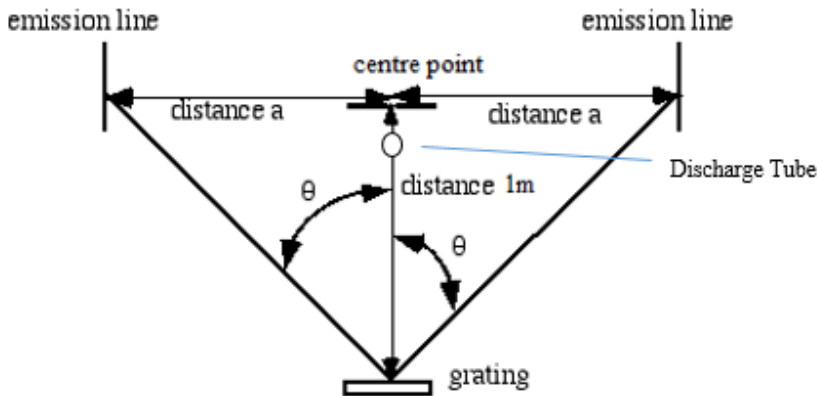


Diagram 3: Portrayal of the necessary measurements for calculations

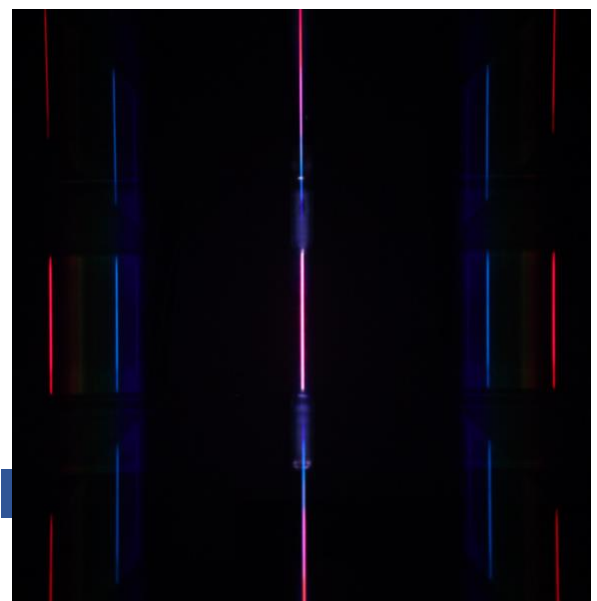
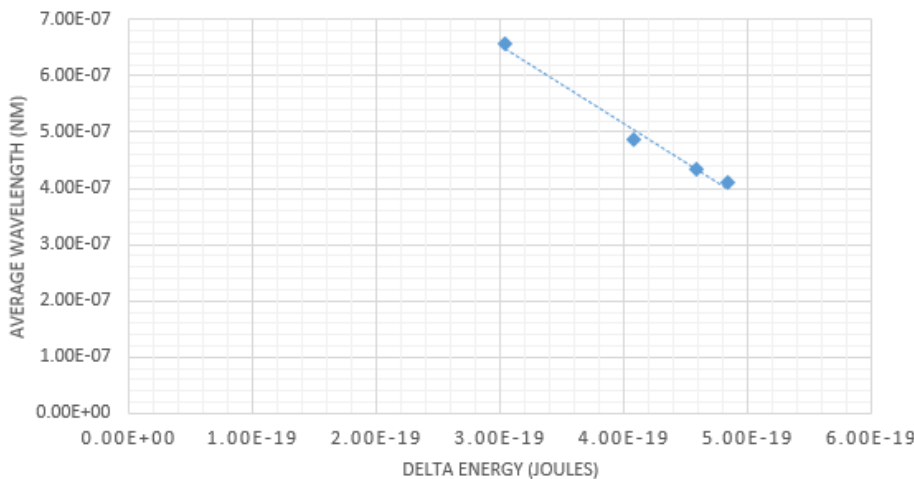
Results:

Wavelength

Hydrogen

| Electron energy jump/ ΔE_{Energy} (Joules) | Wavelength (nm) | | | | | | Average |
|---|-----------------|---------|---------|---------|---------|---------|---------|
| | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | |
| 3-2 3.03×10^{-19} | 656.1 | 656.15 | 656.15 | 656.17 | 656.15 | 656.15 | 656.146 |
| 4-2 4.08×10^{-19} | 486.038 | 486.041 | 486.041 | 486.041 | 486.04 | 486.038 | 486.047 |
| 5-2 4.58×10^{-19} | 433.965 | 433.965 | 433.963 | 433.95 | 433.965 | 433.95 | 433.96 |
| 6-2 4.84×10^{-19} | 410.095 | 410.09 | 410.094 | 410.098 | 410.1 | 410.1 | 410.096 |

RELATIONSHIP OF ENERGY AND WAVELENGTH- HYDROGEN



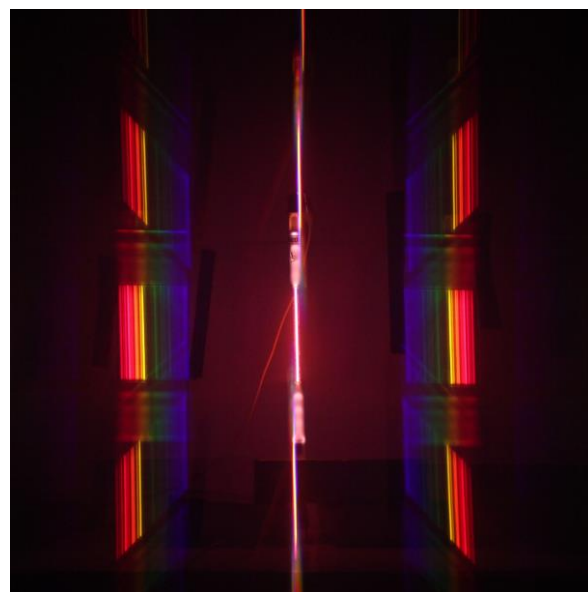
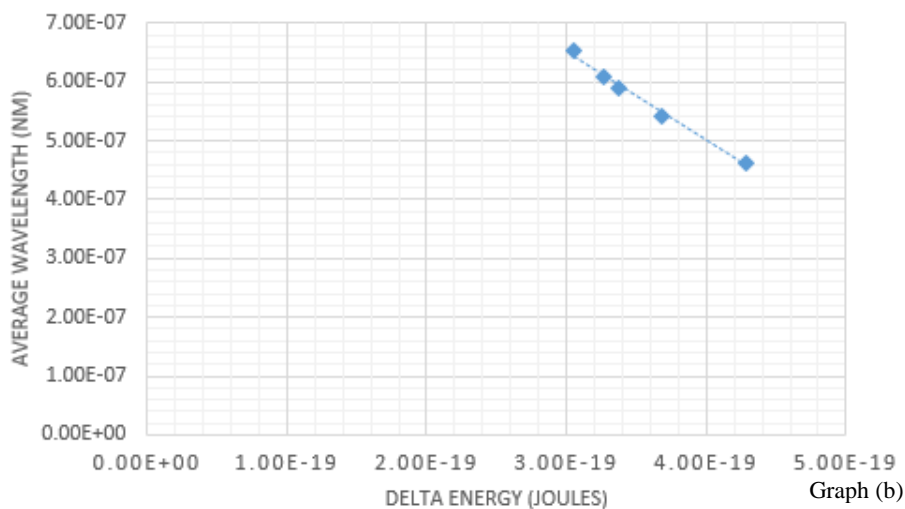
Graph (a)

Hydrogen's Emission Spectrum

Neon

| $\Delta Energy$ (Joules) | Wavelength (nm) | | | | | | |
|-----------------------------|-----------------|---------|---------|---------|---------|---------|---------|
| | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Average |
| 3.05×10^{-19} | 652.37 | 652.35 | 652.37 | 652.4 | 652.36 | 652.37 | 652.37 |
| 3.27×10^{-19} | 607.48 | 607.48 | 607.47 | 607.48 | 607.49 | 607.48 | 607.48 |
| 3.38×10^{-19} | 587.71 | 587.7 | 587.7 | 587.71 | 587.72 | 587.71 | 587.708 |
| 3.68×10^{-19} | 540.13 | 540.12 | 540.13 | 540.12 | 540.12 | 540.13 | 540.108 |
| 4.29×10^{-19} | 463.2 | 463.22 | 463.2 | 463.21 | 463.21 | 463.2 | 463.21 |

RELATIONSHIP BETWEEN ENERGY AND WAVELENGTH- NEON



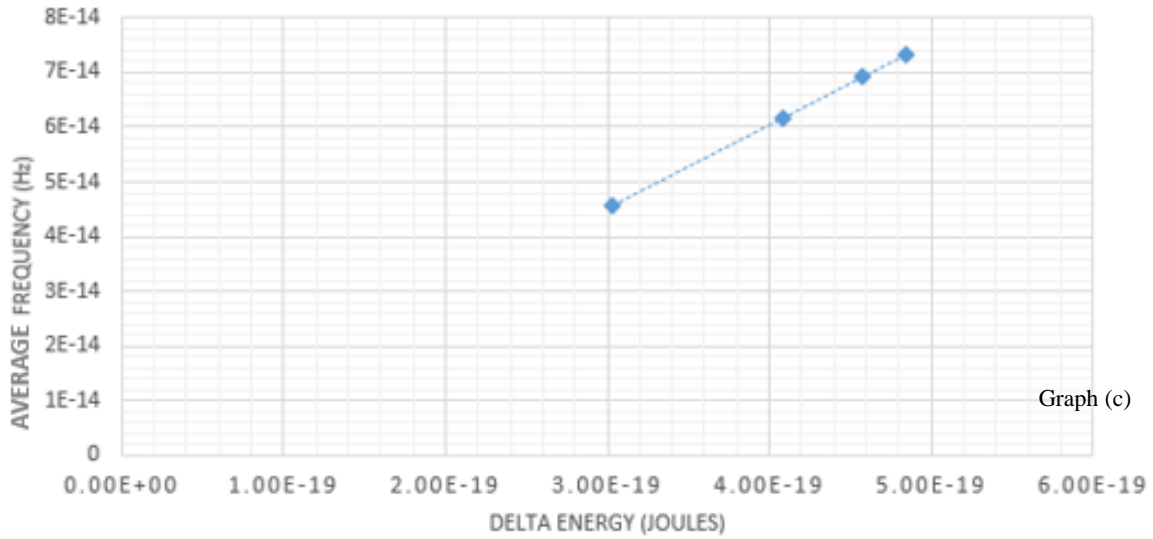
Neon's Emission Spectrum

Frequency

Hydrogen

| Electron Energy Jump/ $\Delta Energy$ (Joules) | Frequency (Hz) | | | | | | |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Average |
| 3-2 3.03×10^{-19} | 4.57×10^{14} | 4.57×10^{14} | 4.57×10^{14} | 4.57×10^{14} | 4.57×10^{14} | 4.57×10^{14} | 4.57×10^{14} |
| 4-2 4.08×10^{-19} | 6.17×10^{14} | 6.17×10^{14} | 6.17×10^{14} | 6.17×10^{14} | 6.17×10^{14} | 6.17×10^{14} | 6.17×10^{14} |
| 5-2 4.58×10^{-19} | 6.91×10^{14} | 6.91×10^{14} | 6.91×10^{14} | 6.91×10^{14} | 6.91×10^{14} | 6.91×10^{14} | 6.91×10^{14} |

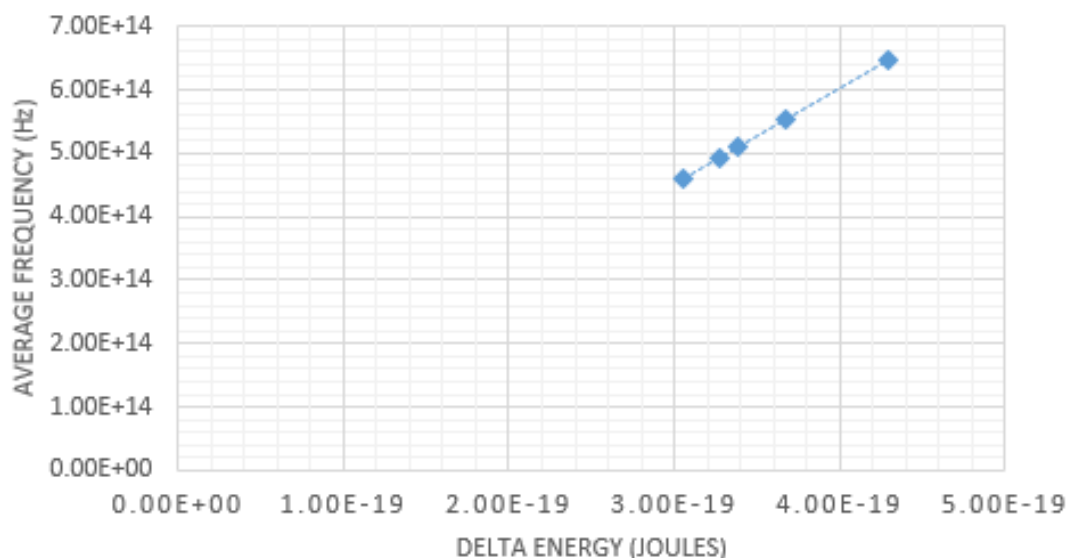
RELATIONSHIP OF ENERGY AND FREQUENCY- HYDROGEN



Neon

| $\Delta Energy$ (Joules) | Frequency (Hz) | | | | | | |
|-----------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Average |
| 3.05×10^{-19} | 4.60×10^{14} | 4.60×10^{14} | 4.60×10^{14} | 4.60×10^{14} | 4.60×10^{14} | 4.60×10^{14} | 4.60×10^{14} |
| 3.27×10^{-19} | 4.94×10^{14} | 4.94×10^{14} | 4.94×10^{14} | 4.94×10^{14} | 4.94×10^{14} | 4.94×10^{14} | 4.94×10^{14} |
| 3.38×10^{-19} | 5.10×10^{14} | 5.10×10^{14} | 5.10×10^{14} | 5.10×10^{14} | 5.10×10^{14} | 5.10×10^{14} | 5.10×10^{14} |
| 3.68×10^{-19} | 5.55×10^{14} | 5.55×10^{14} | 5.55×10^{14} | 5.55×10^{14} | 5.55×10^{14} | 5.55×10^{14} | 5.55×10^{14} |
| 4.29×10^{-19} | 6.47×10^{14} | 6.47×10^{14} | 6.47×10^{14} | 6.47×10^{14} | 6.47×10^{14} | 6.47×10^{14} | 6.47×10^{14} |

RELATIONSHIP OF ENERGY TO FREQUENCY- NEON



Graph (d)

Discussion/Analysis:

The results have brought about significant trends and patterns which were evident in the experiment. To begin, the results answered the aim quite blatantly. The aim of the experiment was to determine how the energy jumps of the electron between orbitals (energy released) affects the wavelength and frequency of the corresponding photon in Hydrogen and Neon atoms. As the results of the experiment were collated, it was evident that as the energy jumps of the electrons between orbitals (ΔE) increased, the wavelength of the electromagnetic radiation decreased. Conversely, as the electron jumps of the electrons between orbitals (ΔE) decreased, the wavelength of the electromagnetic radiation increased. As a result of this trend, they are said to be inversely proportional, as seen in the equation:

$$\Delta E = \frac{hc}{\lambda}$$

Wavelength is a measure of the distance between two successive crests. The experiment clearly shows that this distance is deviated and corresponds to a certain energy. It is important to reiterate that Bohr postulated, through his study of Hydrogen's emission spectrum that as an electron falls from a higher energy state to a lower energy state, energy is given off in the form of a photon. This occurs as energy is being conserved from the drop in energy in the atom. Furthermore, as seen in Graph a and Graph b, the gradients of both graphs are equivalent as -1×10^{12} which tells us that for all energy to wavelength graphs, the gradient must be constant.

Another component of the experiments also brought about an important trend. In regards to the relationship of frequency and the energy released, as the energy jumps of the electrons between orbitals (ΔE) increased, the frequency increased. On the other hand, as the energy jumps of the electrons between orbitals (ΔE) decreased, the frequency decreased. This trend is indicative of the fact that the energy released/electron jump is proportional to the frequency. This is evident in the notable equation:

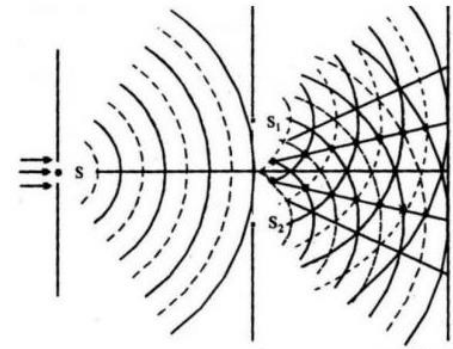
$$\Delta E = hf$$

Frequency is the amount of crests that pass a given point in a given amount of time. This is measured in Hertz, with

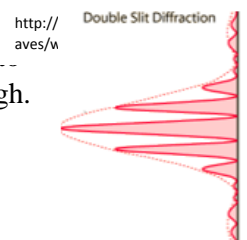
seconds being the given amount of time. Maxwell's theory on the propagation of light, uses Faraday's work on electromagnetism (changing magnetic field creates a potential difference), to illustrate that light is a form of electromagnetic radiation. As electromagnetic radiation has greater amounts of energy, the rate at which the electric fields (\vec{E}) and the magnetic fields (\vec{B}) are created, increase. Additionally, the gradient of Graph c and Graph d are equivalent as 2×10^{33} which tells us that for all energy to frequency graphs, the gradient must be constant.

The emission of a photon only occurs as the atoms are excited, thus, the electron absorbs photons and increases its energy level. As the electron is unstable, it wants to lower its energy state. This is seen through the 2nd Law of Thermodynamics, which states that the entropy (disorder) in a system would remain the same or increase. As the entropy in a system reaches its maximum, it is at a stable position and no change will occur. As it reaches a lower energy state, a photon is released as evident through Bohr's postulates. This photon, as previously mentioned has corresponding energy to the energy difference between the two energy levels by which the electron jumped.

It is important to note the observations that were made in the experiment including facets of dark and light fringes through the diffraction grating, different intensities of light, as well as the striations in the gas discharge tube and their relation to pressure. The dark and light fringes through the diffraction grating occurs due to superposition. As there are several slits in the diffraction grating, when light passes through the slit, constructive and destructive interference occurs. Constructive interference occurs when the crests of two waves meet, whereas destructive interference occurs when the crest of one wave meets the trough of another. This was observed with the Thomas Young's double slit experiment which acts contrary to the way in which light acts with one slit. The diffraction occurs through two slit in the double slit experiment and thus, the waves from both slits interact. These interactions cause light and dark fringes.



As observed, the intensity of light across the orders gradually decreased. This can be explained due to the fact that intensity in regards to light is the measure of the quantity of light waves that pass through. This means that the amount of light that diffracts from the slit in front of the light source (discharge tube) is greater than those light waves that pass through the slits further away from the centre of the light source. The decreasing intensity with order can be observed with the image to the right.



The striations, as evident in the photograph of neon's emission spectrum in the results, depict the fact that the pressure in the gas discharge tubes were approximately 1.33kPa. These are areas of light bands in the discharge tube and occur due to the de-excitation of the electron to a lower energy level, emitting a photon. The dark bands are areas where ionisations occur between collisions of ions and neutral atoms. The atoms absorb the energy, resulting in not only the excitation of the electrons, but the ionisation of the atoms, hence, no light is emitted.

Validity in my experiment was ensured through several avenues. To start, the experiment answered the aim, to determine how the energy released/ electron energy level jump affects the wavelength and frequency. This is evident as the method provides a way of calculating the energy and corresponding wavelength and frequency to accurately determine these factors in regards to the particular gas (hydrogen or neon). As well, all necessary factors were controlled to ensure a fair test, such as potential difference and external light to limit other interferences. This ensured that there was only one possible variable that could have impacted the results and that was the energy released/electron jump. To improve the validity and reliability of the experiment, it was repeated six times, thus, ensuring that consistency with the results was evident. In saying this, the validity and reliability could have most certainly been improved with greater time for greater repetition. Accuracy was ensured as my observations and measurements utilised methods which greatly limited the amount of human error which could occur. Although, in saying this, certain measurements could have been measured to a greater accuracy with better technology that I currently do not possess. For example, I used a diffraction grating and ruler to measure the wavelength and thus, frequency of the particular photon. Instead, by using a spectrometer would have given me results to even four or five decimal places, although this would have only occurred if accessibility to one was enabled.

The experiment I chose to pursue possessed several limitations and factors which had to be deviated in order to

complete it. Initially, I had conducted a trial experiment as I had never previously set up a discharge tube with high voltage. I understood the setup of the experiment due to certain physics websites, as well as YouTube videos which showed the experiment being conducted. After looking at the equipment they had used, I realised that it would be difficult for me to attain the particular equipment needed in order to complete the experiment. The equipment such as the discharge tubes, the induction coil and power pack were the major components in which I needed to attain to complete my experiment. The following were the steps I took to overcome the limitation of inaccessible equipment. I managed to order the discharge tubes on EBay from India, the induction coil from a science supplier in Melbourne and the diffraction grating on EBay from Israel. Additionally, I had no stand for the diffraction grating and the discharge tube. As a result, I used a spare piece of wood with a drilled hole in it as a stand for the discharge tube. For the diffraction grating, I used 4 books as a stand for the diffraction grating.

Another limitation I came across was calculating the electron energy jump of neon. I had previously used the Rydberg Equation in order to calculate the electron jumps in the Balmer series for Hydrogen. The Schrödinger Equation is used to find the electron energy jump for atoms which have more than one electron. Hence, to find the electron jumps for neon, I could use the Schrödinger Equation. The limitation in this situation is the mere fact that you need to know how to integrate in order to use it. I currently do not possess that mathematical knowledge and understanding, thus, I was incapable of making those calculations.

Moreover, the emission spectrum of certain elements emit electromagnetic radiation beyond the scope of the visible spectrum. The limitation in this case is a biological matter. Humans can only see in the visible spectrum and this poses a restraint in the observation of the spectral lines of both hydrogen and neon. Possessing an infrared or UV lens would allow me to see the wavelengths in the Ultra Violet and Infrared spectrum. Without this piece of equipment, I was unable to measure smaller energy and larger energy electromagnetic radiation. This was a great limitation that, in the future, I will attempt to use lenses to see the full emission spectrum of a certain element. Lenses, although, can be expensive and in order to fulfil and answer the aim, the wavelengths in the UV and Infrared aren't completely necessary.

The practical application of the experiment comes in a great multiplicity. To begin, neon lights and panels are used in some plasma displays. The plasma TV is built upon this phenomena. The picture is displayed as Xenon and Neon gas atoms, as well as electrons collide, thus, releasing energy. This energy causes excitations, hence, the electrons jump to a higher energy state and as the electron drops to a lower energy state, it emits a photon. This has had a dramatic impact on the television industry and advancements in technology. As well, the emission spectrum of certain chemicals, especially water are used in space exploration to find certain chemicals on other planets. The emission spectrum of water is used to try and find the corresponding emission spectrum in other areas in the universe. For example, 'indications of the presence of water in the atmosphere of HD 189733b have recently been found in transmission spectra' (*Grillmair et al*, 2008). The study found that the planet HD 189733b, through the emission spectrum, may have water on it, having huge implications for the research into extra-terrestrial life forms beyond the planet earth. In saying this, it is not only limited to finding water, yet, any element, molecule or compound. For example, 'Water (H₂O), methane (CH₄), carbon dioxide (CO₂), and carbon monoxide (CO) have been detected in two hot Jupiters using ground-based observations of the dayside emission spectrum' (*Swain et al*, 2010).

Interestingly, the aurora borealis, or more commonly known as the Northern Lights are a phenomena which uses the same phenomena as the discharge tube to emit light. Essentially, the poles are the only areas where plasma comes into contact with Earth's atmosphere and isn't deflected by Earth's magnetic field. When the atoms in Earth's atmosphere such as Nitrogen, Oxygen and Helium are struck by the plasma, it excites the atoms. As a result, the electrons jump to higher energy levels and as they drop to a lower energy state, due to the conservation of energy, a photon of the energy difference between the two levels n_f and n_i are emitted. The colours vary depending on the quantity and type of gas present in the atmosphere. Oxygen atoms emit green, yellow or red light, while nitrogen atoms emit high frequency blue light. The mixture of all of these colour cause the aurora borealis.

For the future, there are numerous other experiments by which could be conducted in the future. One in which I found really interesting was to determine which angle of the diffraction grating can the emission spectrum be seen. In saying

this, the experiment by which I was keen on conducting, although, didn't have the equipment to undertake it involved taking a sample of unknown compositions of different gases. Once placing these unknown gases into a discharge tube, the emission spectra's of the gases would be observed, and thus, the element could be identified. This links directly to the studies on several planets in order to find the composition of certain elements in their atmospheres. Another interesting experiment would be to mimic J.J. Thompson and place a magnet near the discharge tube to observe the way in which the flow of electron react to the magnet, along with any trends and patterns that are evident.

Conclusion

All in all, the hypothesis was proven to be correct and it is evident that as the electron jump (difference)/energy released increases, the wavelength decreases. This is depicted through the results. When the energy released was 3.03×10^{-19} Joules, the wavelength is 656.146 nanometres, whereas, when the energy released was 4.84×10^{-19} , the wavelength is 410.096 nanometres. As the electron jump (difference)/energy released increases, the frequency increases. This is depicted through the results. When the energy released was 3.05×10^{-19} , the frequency 4.60 Hertz, whereas when the energy released was 4.29×10^{-19} , the frequency was 6.47 Hertz. The trend was consistent amongst both the hydrogen and neon discharge tubes and thus, should be consistent amongst all elements, compounds and molecules.

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