University of Waterloo
Physics & Astronomy

Experiment 18 – Helium Excitation

The basic phenomenon observed in this experiment is the excitation of He atoms to discrete energy states by the impact of electrons. A bulb filled with He vapour contains a filament, anode and collector ring. A voltage is applied to the filament and electrons are emitted. These electrons that leave the hot cathode, which is made of tungsten, are accelerated by the anode. The anode is connected to the inner surface of the bulb, which is coated with a transparent conducting layer made of stannous chloride. Electrons that hit the glass will leak back to the anode via the conducting layer. A collector ring is placed near the anode and has a small positive potential relative to the anode. The ring is positioned so that it cannot receive electrons directly from the cathode.

Electrons that leave the filament and undergo inelastic collisions with the He atoms will lose most of their energy. The He atom will absorb this energy and become excited, meaning an electron in the He atom has jumped to a higher energy state and will decay back, releasing that energy. The impact electron (from the filament) is said to be mono-energetic, neglecting the small thermal energy imparted to it by the filament voltage. These near-zero energy electrons will then be attracted towards the collector ring and a small increase in current will be recorded. You will be able to obtain several current peaks, corresponding to higher excitations. The onset of excitation occurs when the colliding electrons have certain "critical" energies compared to the potential drop between the anode and cathode. Thus, when the mean energy of the electron stream is sufficient to excite He atoms, the population of low energy electrons will increase significantly to produce a measurable current in the collector, with little or no contribution from the main stream.

The principle excitation potentials are shown in Table 1.

PRINCIPAL ENERGY LEVELS OF HELIUM & THEIR CRITICAL POTENTIALS

Ground State	First excitation	Second excitation	Third excitation	Ionization Potential
1^1S – zero eV	2^3S – 19.80 eV	2^1S – 20.61 eV	3^3S – 22.71 eV	24.6 eV
		2^3P – 20.96 eV	3^1S – 22.91 eV	
		2^1P – 21.21 ev	3^3P – 23.00 eV	
			3^1P – 23.08 eV	
AVG:	19.8 eV	20.9 eV	22.9 eV	24.6 eV

* The averages are taken since the tube is not sensitive enough to detect these transitions separately. Therefore only one peak will be observed for the averaged excitation.

The collector current will reach a maximum at some energy above the minimum required for excitation so that the peaks appear at a higher potential than the corresponding energy levels. There are also other factors that will influence the shift in peaks. These include the electron's thermal energy, which contributes to its total energy after acceleration; contact potentials, the externally measured voltages that may differ slightly from those between the internal electrodes; and the zero offset of the xy chart recorder. Despite the observed shift in peaks, the change in separation between peaks will be consistent with the theory.

Therefore, a correction value must be found using the first peak to determine the value of subsequent excitation potentials and ionization.

Prior to ionization, some electrons which are in an excited state may ionize earlier than the remaining majority of electrons. These electrons that are in an excited state are limited since they are populated in a meta-stable state. These states are short lived and occur only in the presence of an external field.

For the initial set up, set the filament voltage to 2.6 volts. This will supply the thermal energy to electrons in the filament. Set the maximum accelerating voltage to 50 volts. A scan should produce a small increase in current between approximately 0-15 volts, 4 distinct peaks in the range of approximately 15-30 volts, and a sharp increase in current for the remainder of the accelerating voltages. Refer to the diagram for characteristics of the plot (included in extra handout). Due to the sensitivity of the apparatus, it is necessary to minimize any external electric fields, as they will easily influence the low energy electrons away from the collector ring. These external fields may result from nearby electrical equipment, overhead fluorescent lights and even people.

In your report, you should include observations of varying the filament voltage. Examine voltages of 1.8, 2.1 and 2.3 and include these scans in your report. Discuss the effect of changing the filament voltage on the overall measured current. Also include any precautions taken to minimize the presence of external electric fields during the experiment.

For the excitation measurements, scan the current produced between accelerating voltages 5 and 35 volts. Scan this region 3 times, using the Y-amplification dial on the xy recorder to magnify the peaks. Carefully determine the voltage values around critical areas of your plot. This information will be used to accurately determine the values of excitation from the experiment. Compare these values with the accepted values of excitation potentials, listed in table 1. Note that the higher energy levels, 4 and 5, should be compared to those deduced from the energy level diagram (included in the handout).

Finally, reverse the current input connections of the xy recorder and switch the polarity of the battery. This will attract the electrons leaving the He atoms and send the low energy impact electrons to the ground. Due to this, a very large increase in the collector current will be observed. Scan two plots between accelerating voltages of 5 and 35 to determine the ionization potential of He, and include these in your report. Don't forget to scale this value by the offset value found for the excitation values.

Notice that there is an area on the ionization plot that indicates a small increase in current, prior to ionization. Discuss this region by giving details on what this is and why it occurs.