Experiment 6

Excitation and Ionization Energies of Neon

6.1 Theory

The essence of this experiment is the demonstration of energy quantization of atoms, Ne in this case. This is achieved via inelastic e^- scattering off Ne atoms. As such it is closely related to the original Franck-Hertz experiment (1914), which showed that an electron must have a certain minimum energy to make an inelastic collision with an atom. We now interpret that minimum energy as the energy of an excited state of the atom. It is strongly advised to read up on the Franck-Hertz experiment.

From a collision standpoint, free electrons colliding with orbiting electrons need to have at least the minimum energy required to excite the bound electrons to higher quantum levels. This experiment involves collecting these electrons after their atomic collisions, and determining the separate excitation energy levels that are available. The theory is quite simple. If an electron collides with a bound electron, and has sufficient energy to "move" the bound electron up into new orbits (or even ionize the atom), then the energy absorbed by the atom is lost to the free electron. This is an inelastic collision, and the free electron will slow down appreciably. In particular, it can now easily be captured by an anode positioned near the beam. As a function of the electron accelerating potential, V_A, the number of electrons captured will increase rapidly near the energy levels of the atomic gas in the tube. These peaks in current will signal the energy levels of the atom.

The enclosed paper by N. Taylor *et al.* gives more details and background information on this type of experiments as well as on the level scheme of Neon.

6.2 Apparatus

- Hertz Critical Potentials tube filled with neon
- Tube stand
- Picoamplifier and Alarmed Meter
- Power Supply and Digital Multimeter

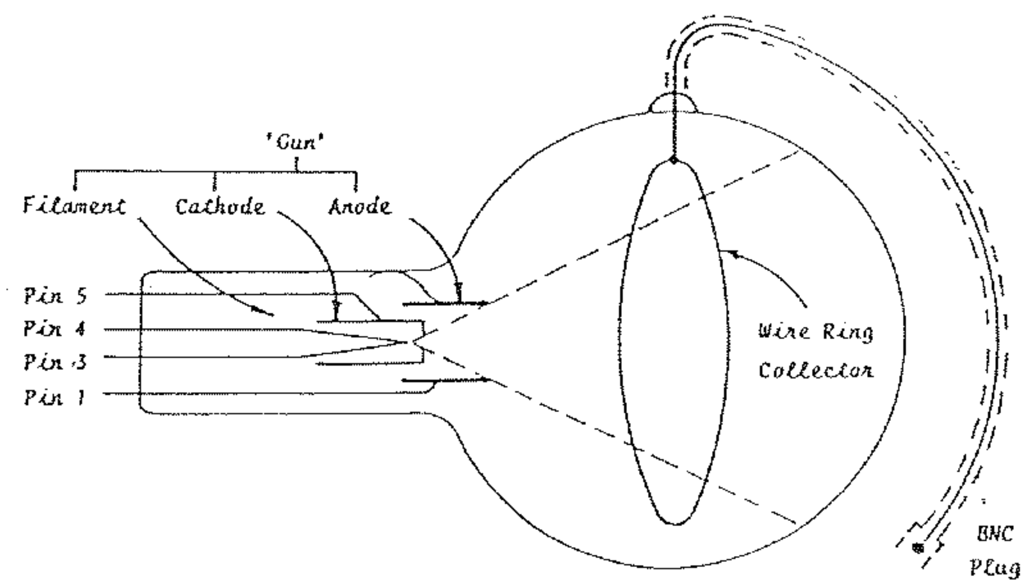
Figs. 6.1 and 6.2 show schematically the tube and circuit diagram. The tube comprises a cathode ray gun which projects a divergent beam of electrons into a clear glass tube containing Neon gas at low pressure. Located inside the bulb is a wire ring collector so positioned that it cannot receive electrons directly from the source of the beam. The ring is connected to a shielded cable terminating in a BNC plug. The source of the beam is a tungsten hairpin filament connected to pins 3 and 4, and housed within a cathode can which is connected to pin 5. The anode cylinder of the gun has an external connection to pin 1. The inside surface of the glass bulb is coated with a transparent conducting layer. This coating is insulated from the wire ring but connected internally to the anode cylinder.

6.3 Objectives

1. Get the hardware to work successfully! This is not completely trivial since you are dealing with a somehat delicate instrument capable of measuring collector currents in the pA range. Any movement close to the glass bulb during scanning of the accelerating voltage should be avoided as it is liable to seriously distort your results.
2. Identify as many energy levels of neon as you can resolve, and determine their excitation energies in eV.
3. Find the ionization energy (in eV) of neon.
4. Measure the energy resolution (FWHM) of the first peak, and any others that you can, or at least give an upper limit if that peak consists of several levels.

6.4 Method

- Set up the apparatus as shown in Fig. 6.2. For the filament voltage V_F use an HP 6213A 12V DC power supply (or similar) capable of delivering $\sim$ 1 A. Important: Do *not* let V_F exceed 2.5 V! Make sure that you zero the alarmed meter at the range


'Gun'
Filament
Cathode
Anode
Pin 5
Pin 4
Pin 3
Pin 1
Wire Ring
Collector
BNC
Plug

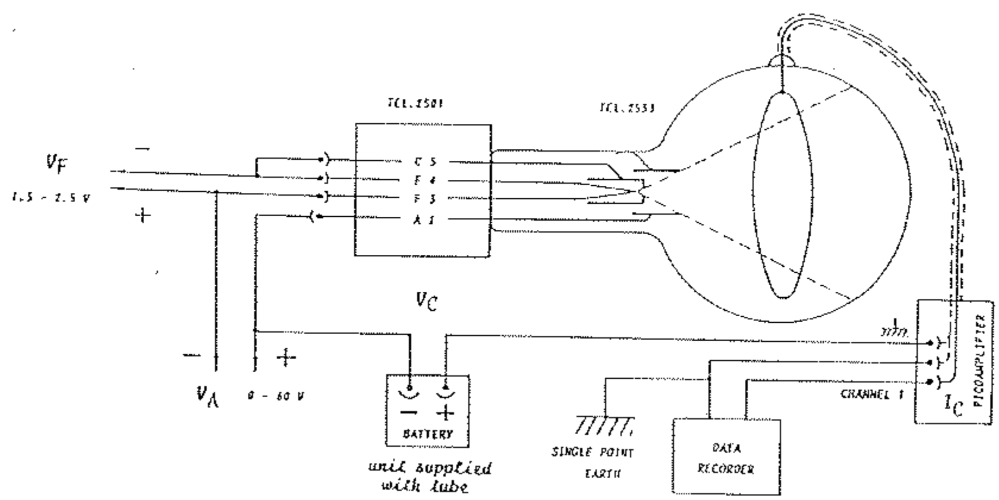


Figure 6.2: Circuit Diagram. For the Data Recorder we use the so-called Alarmed Meter.

setting that you actually end up using. If, for any reason, you decide to play with the range setting you must zero the alarm readings again. You may decide to use a DVM instead of the alarm, and the readings on it will not need to be readjusted. This tube is capable of stable collection currents at constant accelerating voltages, however it is also easily disturbed. If your setup doesn't achieve this stability, examine it for good connection everywhere and disturb the whole table as little as possible while taking your data.

- Vary the accelerating (Anode) voltage V_A and record the collector current I_C. Start with a coarse scan to verify that your results are qualitatively similar to typical results shown in Fig. 6.3. Then do a finer scan to cover the peak regions with sufficient data points. For comparison take data for two different filament voltages V_F. Higher V_F tend to give better peak-to-valley results, i.e. the excitation energy peaks tend to show up more prominently. But remember to *not* exceed 2.5 V for V_F!

- Reverse the potential of the collector ring, and find the ionization potential of neon. Consult Fig. 6.4 for a typical result.

- Check your answers for excitation energies and ionization energy against known values $before$ dismantling the equipment. The ionization energy of Neon is 21.56 eV, and known excitation energies can be found in the paper by N.Taylor *et al.*

6.5 Analysis

Summarize your results, and compare them with known values. What is the electron configuration of the dominant structures that you found? Fig. 6.3 in the enclosed paper by N. Taylor *et al.* will be helpful in this regard. Your peak positions and your ionization energy will likely have a (hopefully more or less constant) offset relative to the known values - how do you explain this?

6.6 References

[1] Melissinos and Napolitano, Chapter 1.
[2] Appendix :"Energy Levels in helium...", Am J. Phys Vol 49 No 3, March 1981.

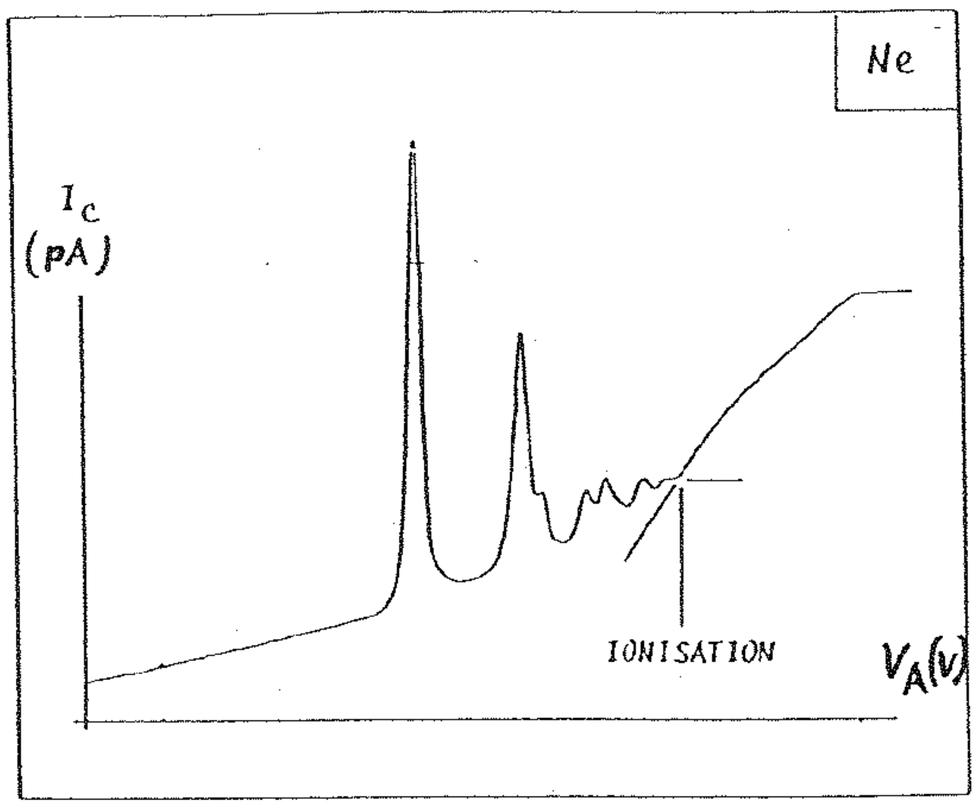


Figure 6.3: Typical excitation energy spectrum for Neon measured with this type of apparatus.

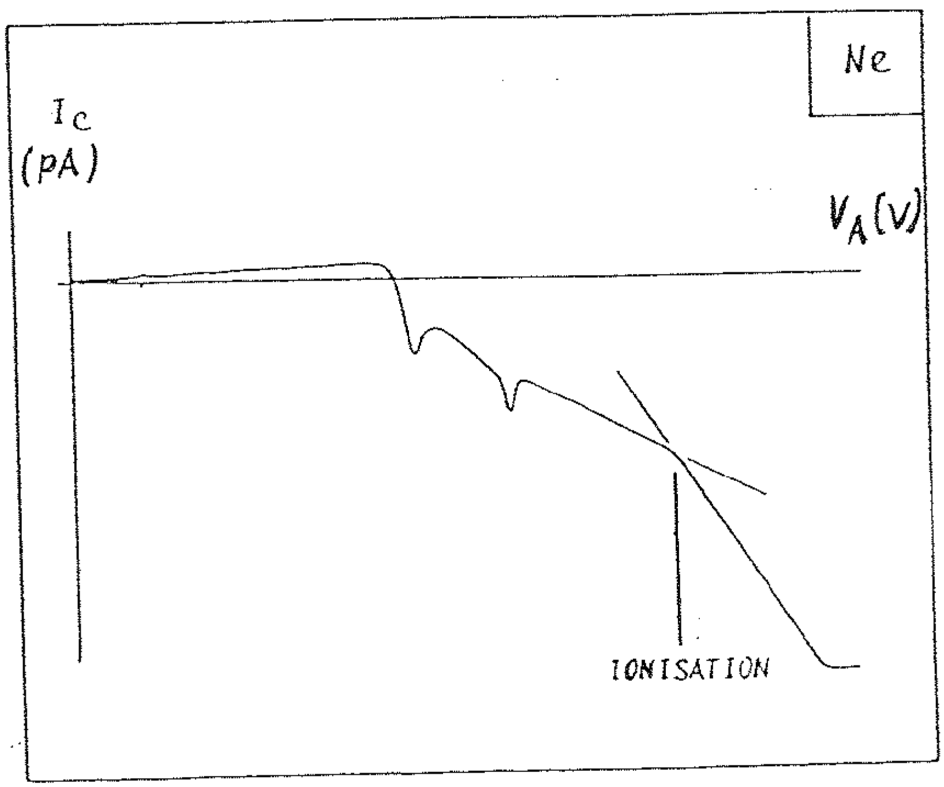


Figure 6.4: Onset of ionization in case of reversed collector bias.