Glow Discharges

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1 Introduction

Luminescent discharges are a fascinating and versatile phenomenon with applications spanning diverse scientific, industrial and technological sectors. These discharges occur in low-pressure gases when an electric field is applied, leading to the ionisation of the gas and the generation of a bright glow.
A glow discharge involves the ionization of gas atoms or molecules in a low-pressure environment, typically in the range of $mbar$. The process begins with the application of an electric field, typically through the use of electrodes within a vacuum chamber. When the electric field intensifies, it imparts energy to gas particles, causing them to ionise and form a plasma, an electrically conductive state of matter composed of charged particles (ions and electrons).

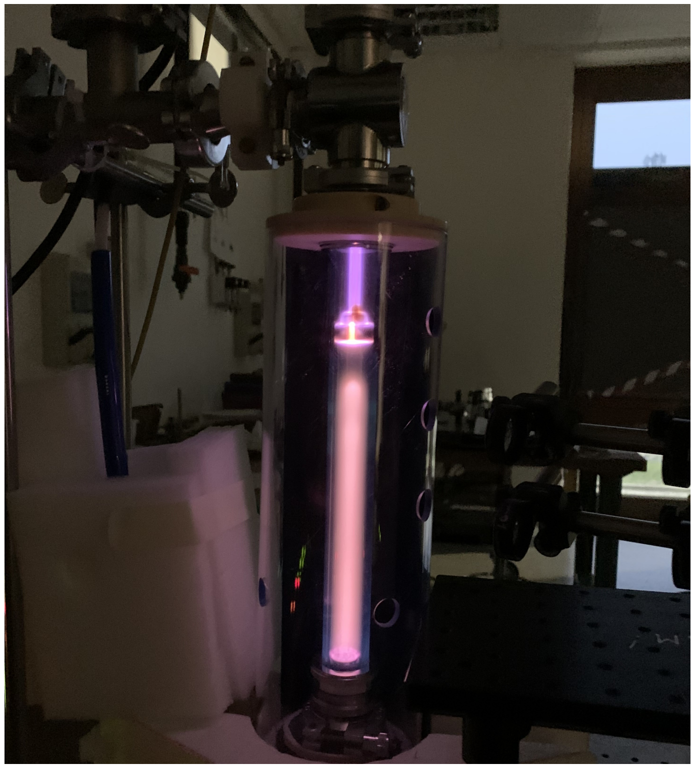
One of the defining characteristics of glow discharges is the visible glow that emerges within the plasma. This bright region is the result of the relaxation of excited electrons to lower energy states, accompanied by the emission of photons. The colour of the luminescence can vary, providing valuable information on the nature of the gas and the discharge conditions.

The goal of the experience is to find the electronic temperature for a monoatomic Argon gas.

2 Set-up

The experimental setup involves a glass chamber at low pressure, around $mbar$, containing two conductors, namely the anode and the cathode. A high-voltage supply energises these conductors to induce plasma formation within the chamber. Argon gas is chosen for this purpose. To limit the current within the plasma, a resistor with a resistance of $30K\Omega$ is incorporated in series.

The initiation of the discharge requires a specific voltage, and this depends on two crucial factors: the separation distance (d) between the anode and the cathode and the pressure (P) inside the chamber, which influences the mean free path of electrons. These parameters are determined by the Pasken curve specific to the chosen gas. This curve illustrates the relationship of the breakdown voltage on the product of pressure and distance.
In a glow discharge, it is possible to see different areas that correspond to different physics phenomena:



In the figure, it is possible to distinguish starting from the top:

- Cathode Dark Space: electrons have not enough energy to excite the atoms
- Negative Glow: atoms de-energize and release photons
- Faraday Dark Space: electrons have lost most of their energy
- Positive Glow: Electric field is mostly constant
- Anode Dark Space

3 Data Analysis

To find the electronic temperature of the glow discharge the following assumptions are taken into consideration:

- All electric levels have the same probability to de-energize
- De-excitation is just radiative
- Just electrons excite atoms' energy levels

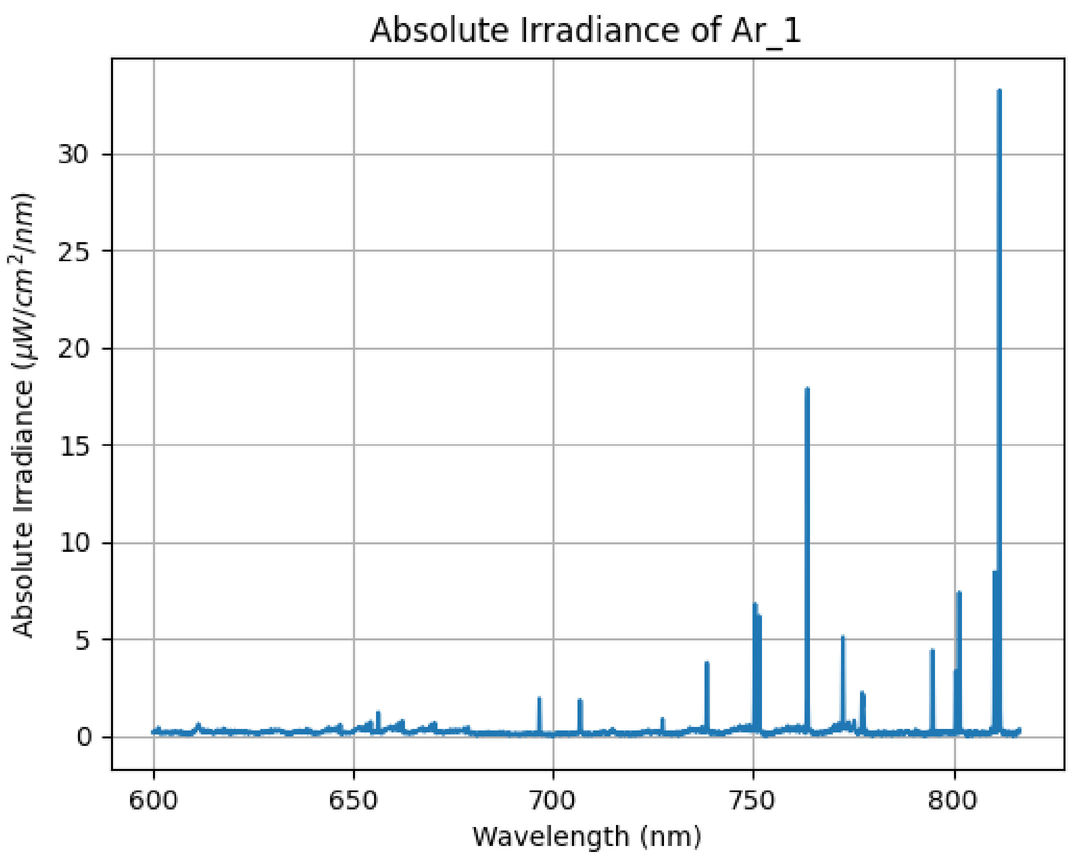
Under these assumptions, the distribution of an energetic level is Boltzmann-like and the state density can be written as:

$$\begin{cases} n_k & \propto g_k e^{-\frac{E_k}{k_B T_e}} \\ n_k & \propto \frac{I_{ki}\lambda_{ki}}{A_{ki}} \end{cases} \tag{1}$$

That can be rewritten as:

$$log\left[\frac{I_{ki}\lambda_{ki}}{g_k A_{ki}}\right] = \frac{E_k}{K_B T_e} + c \tag{2}$$

Where n_k is the density of the state k, E_k is the energy of the state k, K_B is the Boltzmann factor, T_e is the electronic temperature, g_k is the degeneracy of the $k-th$ level, I_{ki} is the intensity from the state i to the state k, A_{ki} is the Einstein coefficient from i to k, λ_{ki} is the wavelength corresponding to the transition from the state i to k and c is a constant.
It's possible to find on the Nist site ("$https://physics.nist.gov/PhysRefData/ASD/lines\_form.html$") the values of g_k, A_{ki} and E_k for the transitions studied, while to find I_{ki} the integrals of the peaks are performed.



Fitting eq. 2 with a line:

$$y = mx + q \tag{3}$$

It's possible to find the electronic temperature as:

$$T_e = \frac{1}{mK_B} \tag{4}$$

Where m is the angular coefficient found by the fit.
It's also possible to find the electronic mean velocity assuming the Maxwell-Boltzmann distribution as:

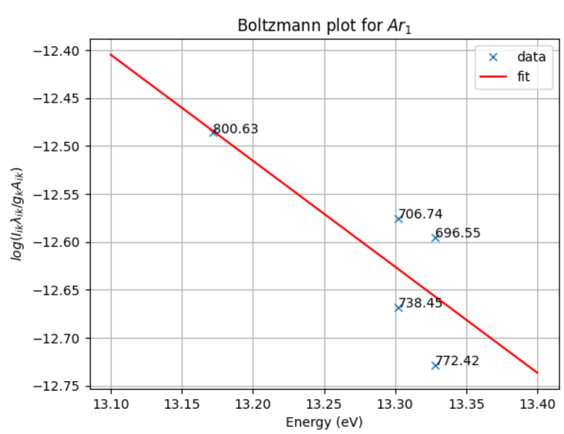
$$v_{MB} = \sqrt{\frac{8K_BT_e}{\pi m_e}} \tag{5}$$

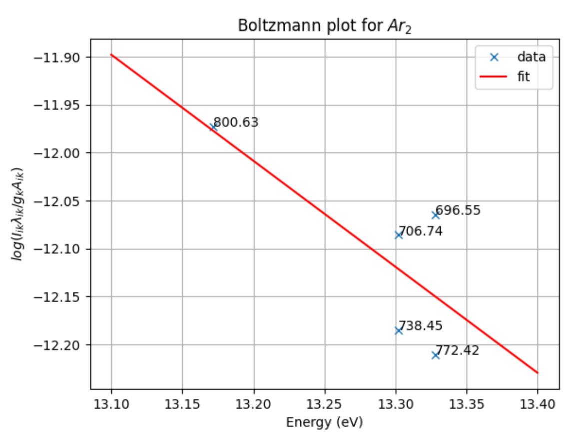
where m_e is the electronic mass.
The following peaks are selected to do the Boltzmann plot:

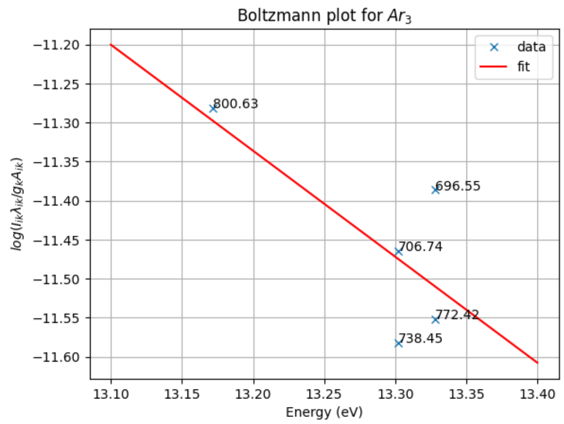
- $\lambda = 696.55 \pm 0.01nm$
- $\lambda = 706.74 \pm 0.01nm$
- $\lambda = 738.45 \pm 0.01nm$
- $\lambda = 772,42 \pm 0.01nm$
- $\lambda = 800.63 \pm 0.01nm$

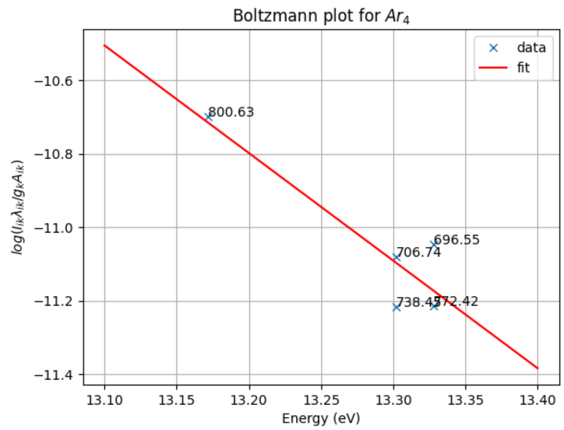
It is done for different values of pressure of the gas and potential difference:

1. Ar_1: $p = 2tor$, $\Delta V = 430V$
2. Ar_2: $p = 2tor$, $\Delta V = 420V$
3. Ar_3: $p = 2tor$, $\Delta V = 419V$
4. Ar_4: $p = 1tor$, $\Delta V = 465V$









	Ar_1	Ar_2	Ar_3	Ar_4
T_e	$10500 \pm 500\ K$	$10500 \pm 500\ K$	$8600 \pm 400\ K$	$4000 \pm 300\ K$
v_e	$(6.4 \pm 0.2) \cdot 10^5 m/s$	$(6.4 \pm 0.2) \cdot 10^5 m/s$	$(5.7 \pm 0.2) \cdot 10^5 m/s$	$(3.9 \pm 0.1) \cdot 10^5 m/s$

4 Conclusions

The values of T_e and v_e decrease as the gas pressure decreases. Decreasing the pressure we expect that the impacts of the particles and thus the ionisations decrease as well, so the electronic temperature and the electronic velocity drop.

With the same pressure, reducing the potential difference, T_e and v_e decrease for the same reason as before.