Task 1 : Ion Identification

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Preface :

Although the plot specifies the x-axis to be in nanometers, I have taken the unit to be in Angstrom (Å) instead. My reasoning for this is as follows:

Assumption : **We're dealing with the gas in vacuum, and not air.**

Using the Rydberg formula for calculating the wavelengths corresponding to the transitions of Hydrogen, we note that:

(a) The shortest wavelength possible is approximately 911.7 Å.

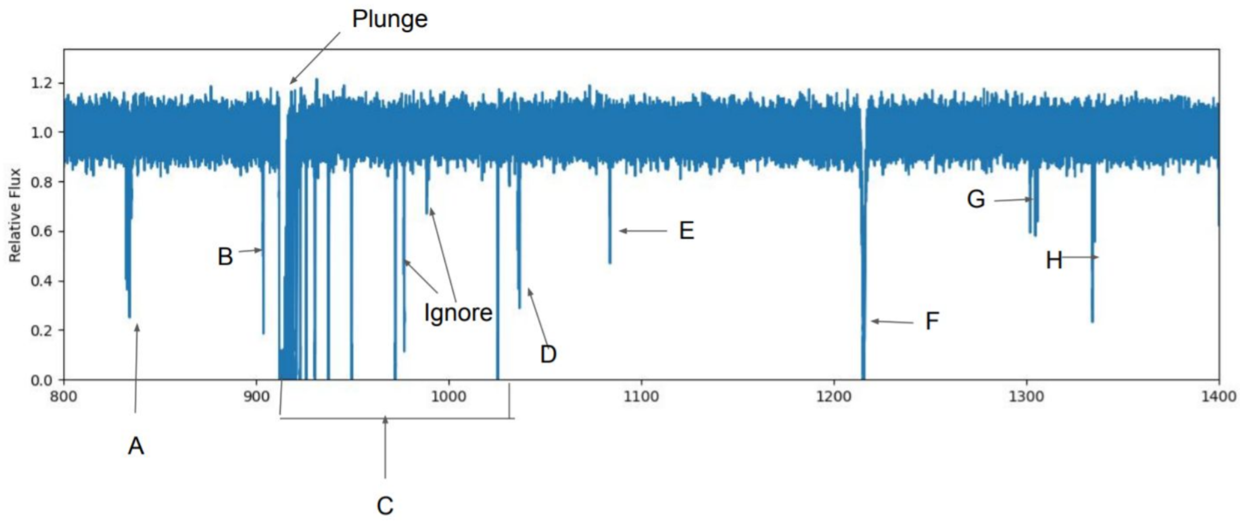
(b) The longest wavelength possible is approximately 1215.7 Å.

Ignoring the unit for now, we can see that the value from (a) corresponds to the "Plunge" at around 900, and the dip at around 1220 also lines up with the value from (b). This leads me to believe that the true unit for the x-axis might not be in nm. The reference cited in the question (https://physics.nist.gov/PhysRefData/Handbook/Tables/hydrogentable2.htm) also appears to corroborate this, as the units provided in the tables there are also in Å and not nm.

For Hydrogen to have transitions in the nm range, the transitions would have to correspond to the Paschen series. But the lower limit for wavelengths of Hydrogen in the series is at around 821 nm, which despite being present on the x axis, does not show any corresponding changes in the y-axis. This observation also is in agreement with the assumption that the unit is probably not nm, but rather Å instead.

Hence, I have assumed the true unit of the x-axis to be in Å and not nm for this task (both parts A and B).

Part (A):



(Fig 1 : The absorption spectrum)

Aim : **<u>To identify the atoms responsible for the features A to H with their ionic state.</u>**

Assumptions : **<u>No close grouping of lines are from different elements.</u>**

Procedure :

The plot in figure (1) has been obtained by plotting wavelength in Angstrom (Å) versus the relative flux. Here, the relative flux is a measurement of the intensity of light observed at a particular wavelength (λ) from an assumed datum. As we are dealing with an absorption spectra, a dip in the relative flux at any given wavelength is assumed to be an indication of the presence of a material which absorbs the electromagnetic radiations. The wavelength these absorptions can be deduced by using Rydberg's equation (below).

$$\frac{1}{\lambda_{vac}} = R_H\left(\frac{1}{n_1^2} + \frac{1}{n_2^2}\right)$$

(Equation 1)

Where,

λ_{vac}: $wavelength\ in\ angstrom\ of\ the\ emitted\ electromagnetic\ wave\ in\ vacuum$

R_H: $Rydberg's\ constant;\ \approx 109677.58\ cm^{-1}\ for\ Hydrogen\ and\ similar\ atoms$

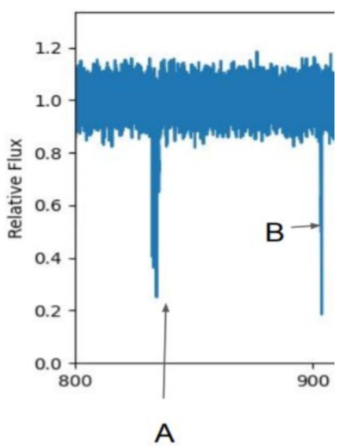
n_1: $Principal\ quantum\ number\ of\ the\ energy\ level$

n_2: $Principal\ quantum\ number\ of\ the\ energy\ level\ for\ the\ electron\ transition$

The values for observed transitions for Hydrogen can be found on the NIST website, and we can look up the values for the other elements from the same website as well. With this information, we can identify the atoms responsible for each feature.

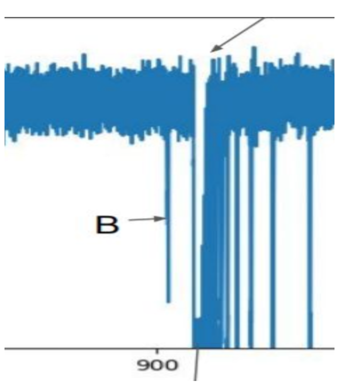
Also, we note here that the intensities provided on the NIST website are relative intensities on a scale of 0 to 1000, and are advised to be used with caution. From the photoelectric effect, we know that absorption can only occur when the intensity of the incident radiation is greater than or equal to the threshold intensity for that particular state.

Note: *Images have been scaled to emphasise and better approximate the wavelengths required for further calculations.*



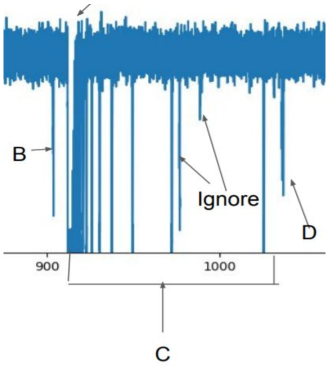
A: Oxygen (II)

From the figure, we can see that there is a dip at approximately one third of the way between 800 and 900. Consulting the tables, we can see that Oxygen (II) absorbs incident radiations between wavelengths 832.7587 and 834.4655 Å, with a relative intensity of 500 (which translates to 0.5 in this scale). As the line 'A' appears to dip to below 0.4 we can conclude that the incident radiation is sufficient enough for the line 'A' to be produced by **Oxygen (II)**.



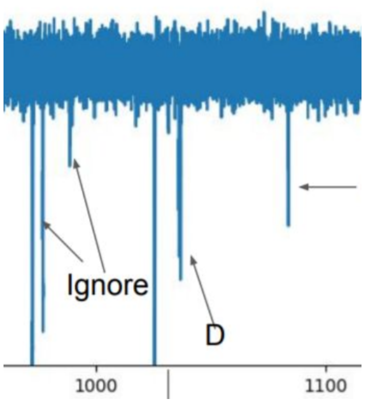
B: Carbon (II)

From the adjacent figure, we can see that the dip at 'B' is slightly greater than and very close to 900. Consulting the tables, we note that Carbon (II) absorbs incident radiations between wavelengths of 903.6235 and 904.4801 Å, with a required relative intensity of 750 (0.75). Hence, we can conclude that the line 'B' is produced by **Carbon (II)**.



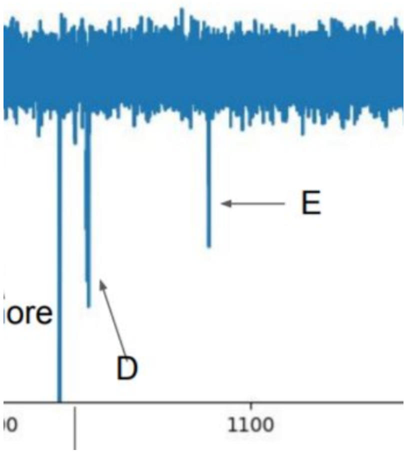
C: Hydrogen (I)

From the Rydberg Formula, we know that the limit of the shortest wavelength produced by Hydrogen is 911.7 Å. We get this value by substituting $n_1 = 1 \; and \; n_2 = \infty$(Lyman Series). Also, we can see that there are many produced lines visible till approximately 1025 Å, which also corresponds with the row from the table for 1025.7222 Å and an intensity of 300 (0.3). This result is also in agreement with the traditional Lyman Hydrogen spectrum. Hence, we can conclude that the element responsible for 'C' is **Hydrogen (I)**.



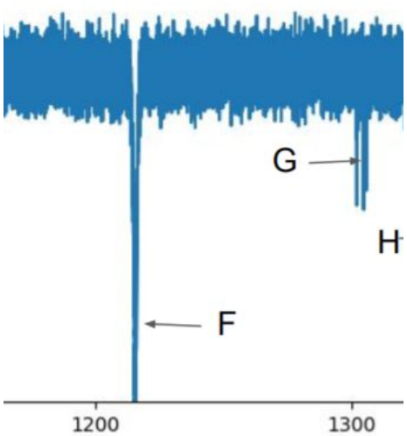
D: Oxygen (I)

From the figure, we can see that the line 'D' is slightly more than one third of the way between 1000 and 1100. This gives it an approximate wavelength of around 1040. From the tables for Oxygen and Carbon, we note that both Oxygen (I) and Carbon (II) absorb incident waves at 1039.230 Å and 1037.0182 Å respectively. When we compare the intensities of each, we notice that Oxygen (I) requires an intensity of 50, whereas Carbon (II) requires an intensity of 500. As the line does not appear to meet the minimum threshold required for Carbon absorptions, we assume that the line belongs to **Oxygen (I)**.



E: Nitrogen (II)

From the figure, we can see that the line 'E' is about four-fifths of the way between 1000 and 1100, which gives us a starting point of around 1080. Upon consulting the tables, we can see that Nitrogen (II) absorbs radiation incident at a wavelength of 1085.710 Å and an intensity of 100 (0.1). Hence, we can conclude that the line 'E' is caused by the presence of **Nitrogen (II)**.

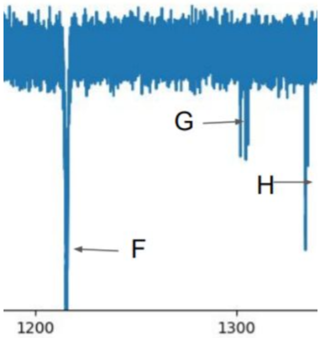


F: Hydrogen (I)

From the Rydberg Formula, we know that the limit of the longest wavelength produced by Hydrogen is 1215.7 Å. We get this value by substituting $n_1 = 1\, and\, n_2 = 2$(Lyman Series). From [the table](), we can see that Hydrogen (I) has a column for 1215.66824 Å and an intensity of 1000 (1), which implies that all radiations at this wavelength are absorbed. This result is also in agreement with the traditional Lyman emission [Hydrogen spectrum](). Hence, we can conclude that the element responsible for 'F' is **Hydrogen (I)**.

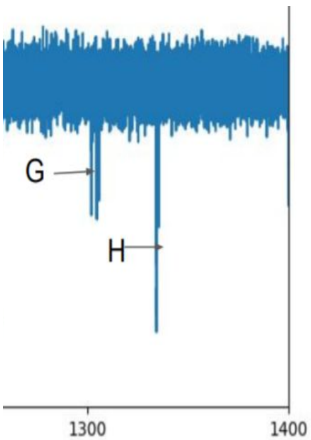
Note : *We can assume the absorption and emission spectra to be "inverses" of each other, because the wavelength at which both phenomena occur is the same, and the processes which produce the radiations are just inverses of each other. In the case of absorption, the electron absorbs the incident photon and "jumps" to a higher energy level (assuming the intensity of the incident photo is greater than the required minimum threshold intensity), while emission deals with an electron "falling" from a higher energy state to a lower one, while releasing a photon in the process.*

Also, for each required minimum incident wavelength intensity for emission, we note that the observed intensity of light at that wavelength has to be less than or equal to 1 - I_{req} (I_{req} being the required incident intensity of radiation) for the element to definitely absorb the radiation.



G: Oxygen (I)

From the figure, we can see that the lines 'G' are very close to 1300. From the tables, we can see that for Oxygen (I) at 1306.029 Å, the relative intensity is 300 (0.3). Hence, we can conclude that this line ('G') corresponds to **Oxygen (I)**.



H: Carbon (I)

From the figure, we can see that the line 'H' is at about 1330. From the table, we can see that for Carbon (I) the wavelength is 1329.5775 Å with a required intensity of 200 (0.2). Hence, we can conclude that the line 'H' implies the presence of **Carbon (I)**.

Part (B):

Although the answers for this question were briefly touched upon in the preface, this section will formally address the same.

1. How are the lines in 'C' related?

   From the Equation (1) (Rydberg's formula) and the explanation of the first line of 'C' from above, we know that the line at 911.7 is predicted from the lower limit of the wavelength of radiation for the Lyman series. The other lines in 'C' can be accounted for by substituting the other various values of $n_2 \in (2, 3, 4, ...)$in the formula. Upon comparison with the emission spectrum of Hydrogen, we can see that the emission lines in the image line up with the absorption spectrum. Hence, we can assume (by correlation) that the lines in 'C' must belong to the element Hydrogen. Hence, we can say that the lines in 'C' are related, <u>because all of them belong to the same element.</u>

2. What causes the “Plunge” near 900?

The plunge near 900 (at 911.7 to be exact) is caused due to the radiations approaching the limit of the Lyman series for Hydrogen. As n_2 approaches infinity, we end up with multiple lines appearing to converge at this wavelength, which causes all radiations in these frequencies to be absorbed by the gas. Hence, we observe a “plunge” here.