Question 15 **(19 marks)**

In 1880, Johannes Rydberg established a mathematical relationship between the wavelengths of light and changes in the relevant energy levels of the hydrogen atom, which is observed in the emission spectrum.

$$\frac{1}{\lambda} = \frac{R}{hc}\left(\frac{1}{n_1^{\,2}} - \frac{1}{n_2^{\,2}}\right)$$

λ = wavelength of light emitted
R = Rydberg's constant
n = the number of the energy levels between which the electron falls (n_2 is always larger than n_1)

The wavelengths of the Lyman series of photons emitted for a hydrogen atom are shown in the diagram below. The Lyman series is made up of all electron transitions to n = 1 i.e. n_1 = 1.

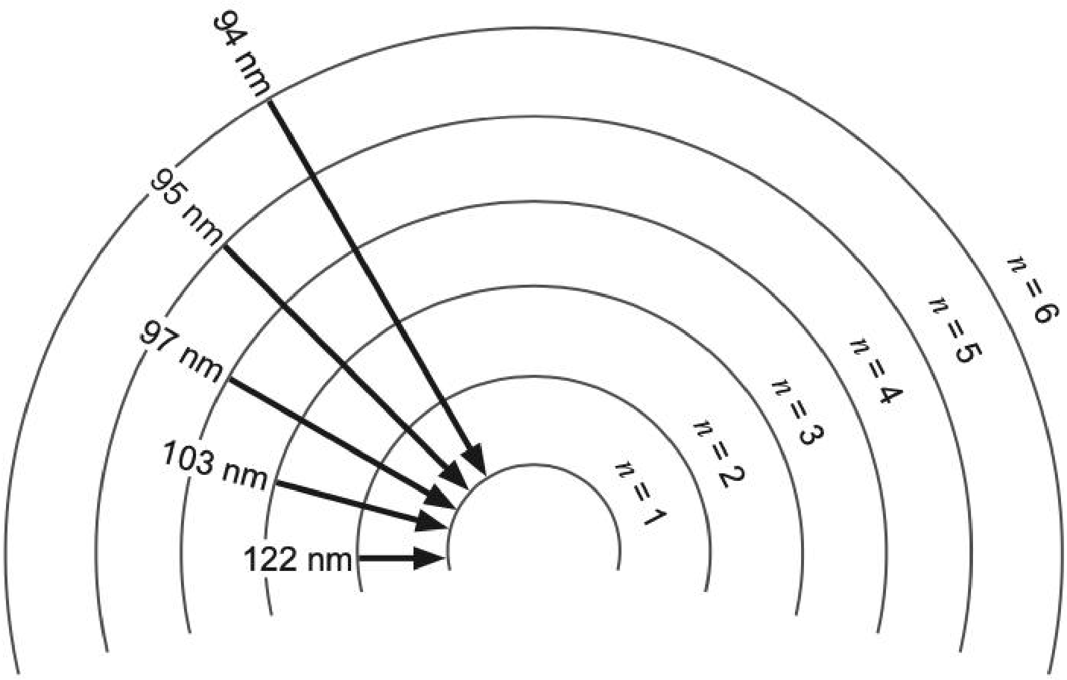
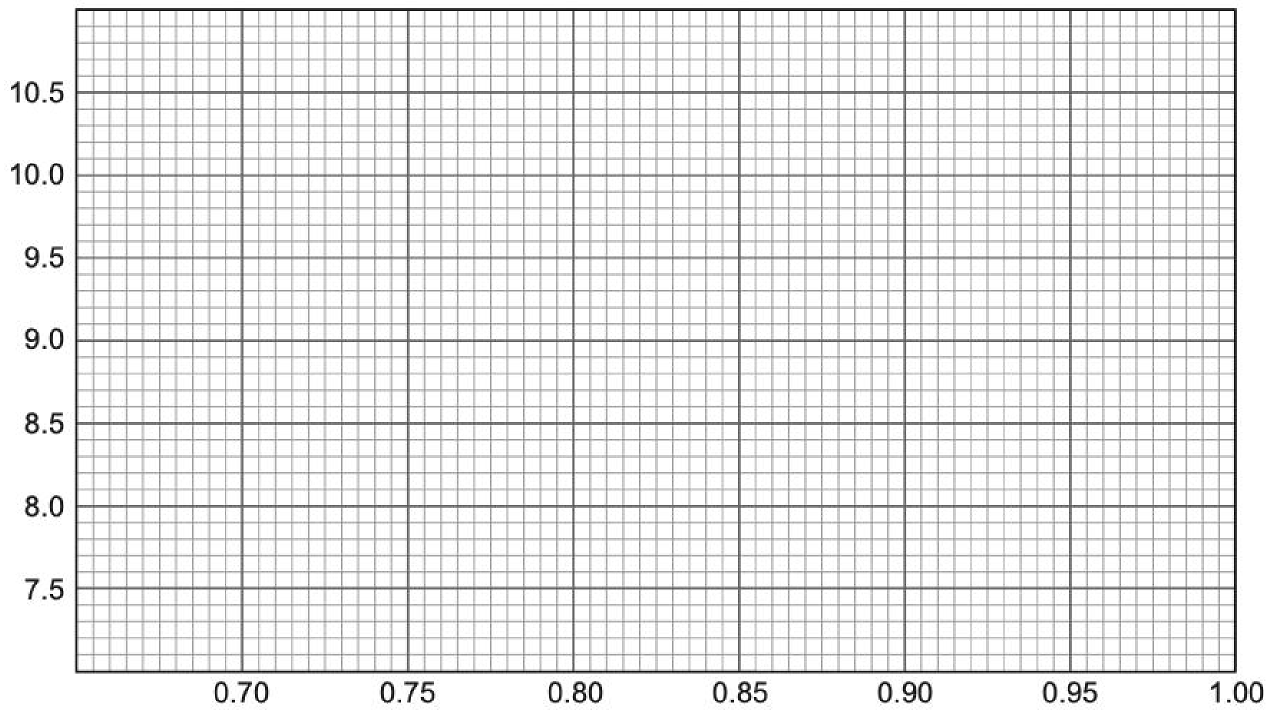


Figure 1: The Lyman series for hydrogen

(a) Fill in the table below using the values in Figure 1. Give your answers to **three** significant figures. (5 marks)

Δn	**2 → 1**	**3 → 1**	**4 → 1**	**5 → 1**	**6 → 1**
$\frac{1}{n_1^{\,2}} - \frac{1}{n_2^{\,2}}$					
$\frac{1}{\lambda}$ (10^6 m^{-1})					

(b) Graph $\frac{1}{\lambda}$ vs $\frac{1}{n_1^{\,2}} - \frac{1}{n_2^{\,2}}$ on the grid below. Label the axes clearly and draw a line of best fit. (5 marks)



A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare grid.

(c) Use your line of best fit to calculate Rydberg's constant. Indicate clearly the points you have used. Give your answer to **two** significant figures. (5 marks)

Answer: ______________________________ J

Rydberg's equation can also be applied to one-electron ions of different elements. The formula is modified to:

$$\frac{1}{\lambda} = Z^2 \frac{R}{hc} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

Z is the atomic number of the element. Figure 2 shows a selection of energy levels for a helium ion ($Z = 2$) and hydrogen atom ($Z = 1$).

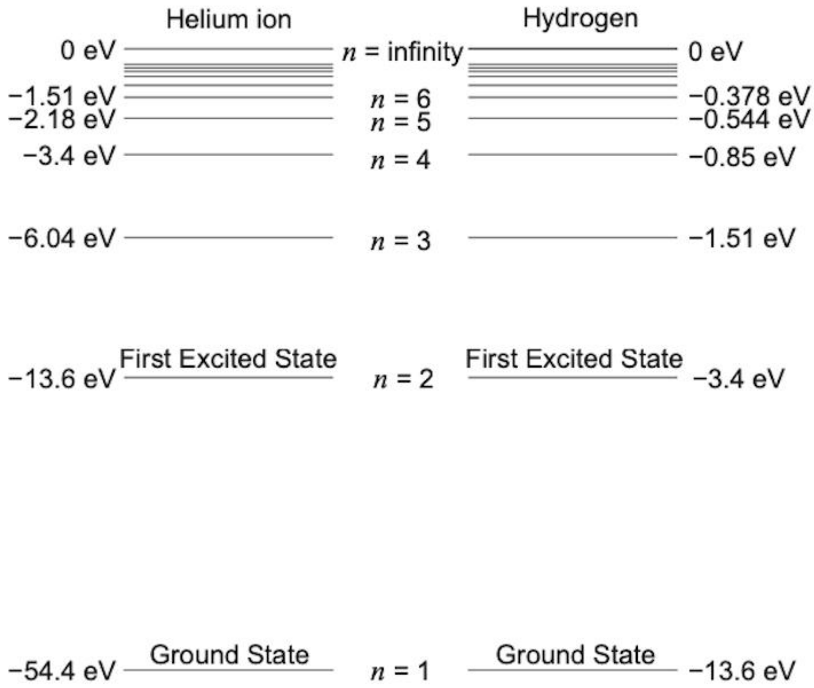


Figure 2: Energy levels for a helium ion and a hydrogen atom

(d) Identify and explain **two** differences you would see between the graph of $\frac{1}{\lambda}$ vs $\frac{1}{n_1^2} - \frac{1}{n_2^2}$ for hydrogen and the helium ion. (4 marks)

One: ______________________________

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Two: ______________________________

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