Physics 262: Physics for Life Sciences II
Section 801: Third Midterm Test Solutions

Section A


Section B

1. An ideal gas in a container of fixed volume has pressure $1.0 \times 10^5 \text{ N/m}^2$ at temperature of $27^\circ \text{C}$. What is the pressure of the gas when the temperature is $327^\circ \text{C}$? (Use $T_{\text{Kelvin}} = 273 + T_{\circ \text{C}}$.)

**Answer:**
For an ideal gas, $pV = Nk_B T$, where $T$ is the temperature in Kelvin. In this question, the pressure and the temperature change. Writing the ideal gas equation twice with subscripts for the quantities which are different, and taking the ratio gives

$$\frac{p_2 V}{p_1 V} = \frac{Nk_B T_2}{Nk_B T_1} \Rightarrow \frac{p_2}{p_1} = \frac{T_2}{T_1} \Rightarrow p_2 = \frac{T_2}{T_1} p_1.$$ 

The initial temperature $T_1 = (273 + 27) \text{ K} = 300 \text{ K}$, and the final temperature is $T_2 = (273 + 327) \text{ K} = 600 \text{ K}$. Therefore, the final pressure is

$$p_2 = \left(\frac{600 \text{ K}}{300 \text{ K}}\right) 1.0 \times 10^5 \text{ N/m}^2 = 2.0 \times 10^5 \text{ N/m}^2.$$
2. For which of the following transitions in a hydrogen atom is the wavelength of the emitted light is shorter? (a) \( n = 3 \) to \( n = 2 \) or (b) \( n = \infty \) to \( n = 3 \). Justify your answer quantitatively.

\[
\text{Note: } \frac{1}{a} - \frac{1}{b} = \frac{b - a}{ab}. \text{ Also, to compare the relative sizes of fractions, manipulate the fractions so that they have the same denominator (number at the bottom) and compare the numerators. }
\]

**Answer:**

Since \( f \lambda = c \) (where \( f \) is the frequency, \( \lambda \) is the wavelength and \( c \) is the speed of light) and \( E_{\text{photon}} = hf \Rightarrow E_{\text{photon}} = hc/\lambda \). Therefore, the shorter wavelength of light (smaller \( \lambda \)) corresponds to the larger \( E_{\text{photon}} \).

The energy levels of the hydrogen atom are \( E_n = -E_R/n^2 \), where \( n \) is an integer and \( E_R = 13.6 \text{eV} \). By conservation of energy, the energy of the photon emitted is

\[
E_{\text{photon}} = E_{\text{initial}} - E_{\text{final}} = -\frac{E_R}{n_{\text{initial}}^2} - \left( -\frac{E_R}{n_{\text{final}}^2} \right) = E_R \left( \frac{1}{n_{\text{final}}^2} - \frac{1}{n_{\text{initial}}^2} \right).
\]

Using this for the two cases gives

(a) \( E_{\text{photon},(a)} = E_R \left( \frac{1}{2^2} - \frac{1}{3^2} \right) = E_R \left( \frac{1}{4} - \frac{1}{9} \right) = E_R \left( \frac{9 - 4}{9 \times 4} \right) = \frac{5}{36} E_R \).

(b) \( E_{\text{photon},(b)} = \left( \frac{1}{3^2} - \frac{1}{\infty^2} \right) = \frac{1}{9} E_R = \frac{4}{4 \times 9} E_R = \frac{4}{36} E_R \).

So, **(a)** has the larger energy and corresponds to the emission line with the shorter wavelength.