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**ASSIGNMENT 1:**  
Pressure, Temperature,  
Ideal Gas Equation.

UNIVERSITY OF OTTAWA  
Principles of Physics  
PHY1321/31 Fall 2018  
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Released: Sept 14 Due: Sept 21 6PM

Each question is marked out of 4 points, In addition to this there are 4 points for presentation/aesthetics for the whole assignment

- 1 HS teacher duplicated Torricelli's barometer using a mineral oil, of density  $1230 \text{ kg/m}^3$ , as the working liquid. What was the height  $h$  of the oil column for normal atmospheric pressure?

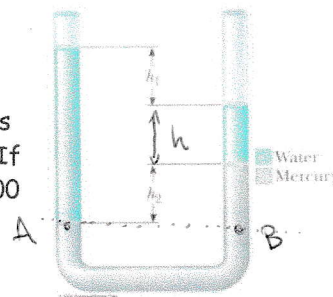
$$P_0 = \rho g h$$

$$h = \frac{P_0}{\rho g}$$

$$= 101,300 \text{ Pa} \left( \frac{1}{1230 \frac{\text{kg}}{\text{m}^3}} \right) \left( \frac{1}{9.81 \frac{\text{m}}{\text{s}^2}} \right)$$

$$= 8.40 \text{ m}$$

- 2 A U-tube of uniform cross-sectional area, open to the atmosphere, is partially filled with mercury. Water is then poured into both arms. If the equilibrium configuration of the tube is as shown in, with  $h_2 = 1.00 \text{ cm}$ , determine the value of  $h_1$ .



Let  $h$  be the height between  $h_1$  and  $h_2$ .

$P(\text{left}) = P(\text{right})$  as they are in equilibrium conf (Pressures at A and B are equal).

Since areas (A) are the same and pressures (P) are the same, forces (F) must be the same.

$$F(\text{left}) = F(\text{right})$$

$$F(\text{left}) = P_{\text{atm}} + (h_1 + h + h_2) \rho_{\text{H}_2\text{O}} g$$

$$F(\text{right}) = P_{\text{atm}} + h \rho_{\text{H}_2\text{O}} g + h_2 \rho_{\text{Hg}} g$$

$$P_{\text{atm}} + (h_1 + h + h_2) \rho_{\text{H}_2\text{O}} g = P_{\text{atm}} + h \rho_{\text{H}_2\text{O}} g + h_2 \rho_{\text{Hg}} g$$

$$(h_1 + h_2) \rho_{\text{H}_2\text{O}} = h_2 \rho_{\text{Hg}}$$

$$(h_1 + 1.00 \text{ cm})(1000 \frac{\text{kg}}{\text{m}^3}) = (1.00 \text{ cm})(13600 \frac{\text{kg}}{\text{m}^3})$$

$$h_1 = 12.6 \text{ cm}$$

- 3 a) Show that 1 mole of any gas at atmospheric pressure and at  $0^\circ \text{C}$  is taking 22.4 liters of volume  
 (b) Show that the density of an ideal gas occupying a volume  $V$  is given by  $PM/RT$ , where  $M$  is the molar mass.  
 (c) Determine the density of oxygen gas at atmospheric pressure and  $20.0^\circ \text{C}$ .

a)  $PV = nRT$   
 $V = \frac{nRT}{P}$   
 $V = (1 \text{ mol})(0.0821 \frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}})(273 \text{ K})$   
 $V = 22.4 \text{ L}$

b)  $PV = nRT$  # number of moles =  $\frac{\text{Weight}}{\text{molecular weight}}$   
 $PV = \left( \frac{W}{M} \right) RT$   
 $PM = \left( \frac{W}{V} \right) RT$   
 $PM = \rho RT$   
 $\rho = \frac{PM}{RT}$

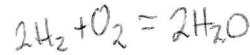
c)  $\rho = \frac{PM}{RT}$   
 $\rho = \frac{(1 \text{ atm})(32 \frac{\text{g}}{\text{mol}})}{(0.0821 \frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}})(293 \text{ K})}$   
 $\rho = 1.33 \text{ g/L}$

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ASSIGNMENT 1: CONT

4 100 grams of oxygen and 40 grams hydrogen gas occupy separate, equal sections of 200 liter tank. The divide is removed and the gases are allowed to mix and react with each other. The temperature is kept constant at 130 °C, throughout the process

- a) find the pressure of each gas in the separate containers  
b) find the pressure after the reaction ends.



b)  $O_2$  is the limiting reactant as the reaction will stop after all  $O_2$  is used up (this will happen when  $2 \times 100$  mol of  $H_2$  are used as  $H_2$  and  $O_2$  are in a 2:1 ratio. This means that only  $\frac{200}{32}$  mol  $H_2O$  (2:2 ratio) and  $(19.8 - \frac{200}{32})$  mol of  $H_2$  are left.

a) ①  $PV = nRT$

$P_{O_2} = ?$

$V_{O_2} = 100L$

$n_{O_2} = 100g_{O_2} \times \frac{1 \text{ mol } O_2}{32.0g_{O_2}} = 100/32 \text{ mol } O_2$

$R = 0.0821 \frac{\text{atm} \cdot L}{\text{mol} \cdot K}$

$T_{O_2} = 403K$

②  $PV = nRT$

$P_{O_2} = \frac{(\frac{100}{32} \text{ mol } O_2)(0.0821 \frac{\text{atm} \cdot L}{\text{mol} \cdot K})(403K)}{100L}$   
 $= 1.034 \text{ atm}$

①  $PV = nRT$

$P_{H_2} = ?$

$V_{H_2} = 100L$

$n_{H_2} = 40g_{H_2} \times \frac{1 \text{ mol } H_2}{2.02g_{H_2}} = 19.8 \text{ mol } H_2$

$R = 0.0821 \frac{\text{atm} \cdot L}{\text{mol} \cdot K}$

$T_{H_2} = 403K$

②  $PV = nRT$

$P_{H_2} = \frac{(19.8 \text{ mol } H_2)(0.0821 \frac{\text{atm} \cdot L}{\text{mol} \cdot K})(403K)}{100L}$   
 $= 6.55 \text{ atm}$

①  $P_{H_2O} V = nRT$

$P_{H_2O} = \frac{(\frac{200}{32} \text{ mol})(0.0821 \frac{\text{atm} \cdot L}{\text{mol} \cdot K})(403K)}{200L} = 1.034 \text{ atm}$

②  $P_{H_2} V = nRT$

$P_{H_2} = \frac{(19.8 - \frac{200}{32} \text{ mol})(0.0821 \frac{\text{atm} \cdot L}{\text{mol} \cdot K})(403K)}{200L} = 2.24 \text{ atm}$

③  $P_{\text{total}} = P_{H_2} + P_{H_2O}$   
 $P_{\text{total}} = 1.034 + 2.24$   
 $P_{\text{total}} = 3.27 \text{ atm}$

A telescope forms an image of part of a cluster of stars on a square silicon charge-coupled detector (CCD) chip 2.00 cm on each side. A star field is focused on the CCD when it is first turned on and its temperature is 27.0°C. The star field contains 5 432 stars scattered uniformly. To make the detector more sensitive, it is cooled to -173°C. How many star images then fit onto the chip? The average coefficient of linear expansion of silicon is  $4.68 \times 10^{-6} (\text{°C})^{-1}$ .

① # stars = 5,432 (in frame)

$l_1 = 2.00 \text{ cm}$

$T_1 = 27.0^\circ C$

$T_2 = -173^\circ C$

$\alpha = 4.68 \times 10^{-6} (\text{°C})^{-1}$

②  $A_1 = (2.00 \text{ cm})^2 = 4.0 \text{ cm}^2$



if 5,432 stars scattered every  $4 \text{ cm}^2$ , there are 1,358 stars/ $\text{cm}^2$

③  $\Delta L = \alpha L_1 \Delta T$

$l_2 - l_1 = \alpha L_1 \Delta T$

$l_2 = l_1 (1 + \alpha \Delta T)$

$= (2.00 \text{ cm})(1 + (4.68 \times 10^{-6} / \text{°C})(-173^\circ C - 27^\circ C) + 1)$   
 $= 1.998128 \text{ cm}$

④  $A_2 = (1.998128)^2 = 3.9925 \text{ cm}^2$

⑤ How many stars?

? stars # =  $3.9925 \text{ cm}^2 \times \frac{1,358 \text{ stars}}{\text{cm}^2} = 5,421.84 \text{ stars}$