UNIVERSITY OF OTTAWA
Principles of Physics
PHY1321/31 Fall 2017
Dr. A. Czaikowski

STUDENT #: ______________

NAME: ____________________

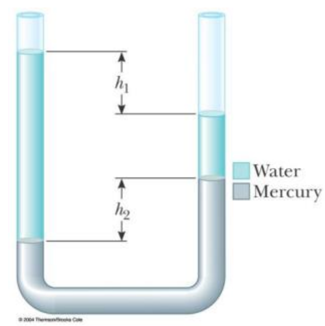
ASSIGNMENT 1:
Pressure, Temperature, Ideal Gas Equation

Released: Sept 15 **Due: Sept 22** **6PM**

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

Since $P_0 = \rho gh$ $\qquad h = \frac{P_0}{\rho g} = \frac{1.013\times10^5 Pa}{(1230 kg/m^3)(9.81 kg/ms2)} = 8.40m$

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 cm, determine the value of h_1.



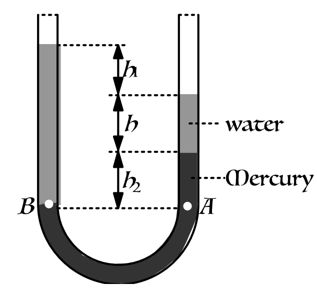
Let h be the height of the water column added to the right side of the U–tube. Then when equilibrium is reached, the situation is as shown in the sketch at right. Now consider two points, A and B shown in the sketch, at the level of the water–mercury interface. By Pascal's Principle, the absolute pressure at B is the same as that at A. But,

$$P_A = P_0 + \rho_w gh + \rho_{Hg} gh_2 \text{ and}$$

$$P_B = P_0 + \rho_w g(h_1 + h + h_2).$$

Thus, from $P_A = P_B$, $\rho_w h_1 + \rho_w h + \rho_w h_2 = \rho_w h + \rho_{Hg} h_2$, or

$$h_1 = \left[\frac{\rho_{Hg}}{\rho_w} - 1\right] h_2 = (13.6-1)(1.00 \text{ cm}) = \boxed{12.6 \text{ cm}}$$



3 a) Show that 1 mole of any gas at atmospheric pressure and at 0° 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°C.

a) $pV = nRT \Rightarrow (101000)V = (1)(8.31)(273) = 0.0224 m^3 = 22.4 l$

b) $pV = nRT \Rightarrow pV = \frac{m}{M}RT \Rightarrow \frac{pM}{RT} = \frac{m}{V} \Rightarrow \rho = \frac{pM}{RT}$

c) $\rho = \frac{pM}{RT} = \frac{(101300)(0.032)}{(8.31)(293)} = 1.331 \frac{kg}{m^3}$

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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.

There are 3.125 moles of molecular oxygen gas in the first section, so

$$P_iV_i = nRT \Rightarrow P_i(O_2) = \frac{3.125 \cdot 8.31 \cdot 403}{0.1} Pa = 104654.06 Pa = 105 kPa$$

There are 20 moles of molecular hydrogen gas in the first section, so

$$P_iV_i = nRT \Rightarrow P_i(H_2) = \frac{20 \cdot 8.31 \cdot 403}{0.1} Pa = 669786 Pa = 700 kPa$$

B) after the reaction there will be 6.25 moles of steam and 10 moles of molecular hydrogen in a 200 liter container. The final pressure will be a sum of the partial pressures taken independently

$$\boldsymbol{P_fV_f = nRT \Rightarrow P_f(H_2O) = \frac{(6.25)\,(8.31)\,(403)}{0.2} Pa = 104654.06 Pa = 105 kPa}$$

$$P_fV_f = nRT \Rightarrow P_f(H_2) = \frac{(10)\,(8.31)\,(403)}{0.2} Pa = 167446.5 = \boldsymbol{167 kPa}$$

ANS: total pressure after the reaction is 272kPa

5 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 4.68×10^{-6} $(°C)^{-1}$.

$$\Delta S = \gamma S \Delta T = 2\alpha S \Delta T = 2(4.68 \cdot 10^{-6}) \cdot (4) \cdot (-200) cm^2 = -0.007488 cm^2$$

$$S_f = S_i + \Delta S = 3.992512 cm^2$$

$$N_f = \frac{N}{S_i} S_f = \frac{5432}{4} 3.992512 = 5421.83 = 5421\ full\ stars$$