TOTAL = 32

CHM1311 B: Principles of Chemistry

Prof. N. Goto
Assignment #2
Due Oct 3rd, at the beginning of class

Solutions must be written legibly, in the space provided. Adequate detail to the calculation (including units, appropriate sig figs) must be provided to make it possible for other students to understand how you arrived at the final solution. If more space is needed, use the back of the page. Do not add extra pages, as they will not be marked. Assignment pages must be stapled together.

Assignments can be submitted individually, or by groups of up to 4 students.

1) Name: ________________ **Student ID:** ______________

2) Name: ________________ **Student ID:** ______________

3) Name: ________________ **Student ID:** ______________

4) Name: ________________ **Student ID:** ______________

NOTE: For each question an on-line resource in WileyPLUS is given in brackets that can walk you through a similar type of problem. (ILW = Interactive Learning Ware.)

Question 1. (Office hours video 2.8)

A bicycle pump inflates a tire whose volume is 502 mL until its internal pressure is 5.30 bar at a temperature of 20.5 °C.

a) How many moles of air is contained in the tire?

$V = 502\ mL \quad p = 5.30\ bar \quad T = 20.5\ °C = (273.15 + 20.5)\ K = 293.65\ K$

$n = \frac{pV}{RT}$

$= \frac{(5.30\ bar)(502\ mL)(10^{-3}\ L\ mL^{-1})}{(0.08314\ bar \cdot L \cdot K^{-1} mol^{-1})(293.65\ K)} = 0.109\ mol$

(2)

b) What volume of air at 1.00 atm and 20.5 °C did the pump transfer?

∵ T, n IS THE SAME AS IN PART a)

$p_1 V_1 = p_2 V_2$

$V_2 = \frac{p_1 V_1}{p_2} = \frac{(5.30\ bar)(502\ mL)}{(1.00\ atm)(1.01325\ bar\ atm^{-1})}$

$= 2626\ mL = 2.63\ L$

(1)

Question 2. (Video problem 2.17)

Imagine that unknown gas in a storage tank is analyzed. A 25.89 g sample of the gas contains 9.71 g butane (C_4H_{10}), 7.54 g ammonia, and 8.64 g molecular nitrogen. Calculate the partial pressures of each gas (in bar) in the storage tank if the total pressure in the tank is 3.45 bar.

$n_{C_4H_{10}} = \frac{9.71\ g}{(4\times12.01 + 10.008)\ g/mol} = 0.1671\ mol$

$n_{NH_3} = \frac{7.54\ g}{(14.01 + 1.008\times3)\ \frac{g}{mol}} = 0.4426\ mol$

$n_{N_2} = \frac{8.64\ g}{(2\times14.01)\ \frac{g}{mol}} = 0.3084\ mol$

$n_T = n_{C_4H_{10}} + n_{NH_3} + n_{N_2}$
$= 0.1671\ mol + 0.4426\ mol + 0.3084\ mol$
$= 0.9181\ mol$

$\chi_{C_4H_{10}} = \frac{n_{C_4H_{10}}}{n_T} = \frac{0.1671\ mol}{0.9181\ mol} = 0.1820$

③

$P_{C_4H_{10}} = \chi_{C_4H_{10}} P_T$
$= (0.1820)(3.45\ bar)$
$= 0.628\ bar$

Question 3. (Video 25)

Carbon monoxide and molecular oxygen react to form carbon dioxide. A 50.0 L reactor at 25.0 °C is charged with 1.00 bar of CO. The gas is then pressurized with O_2 to give a total pressure of 3.26 bar. The reactor is sealed, heated to 350 °C to drive the reaction to completion, and cooled back to 25.0 °C.

Compute the final partial pressure of each gas (in bar).

$CO_{(g)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{2(g)}$

FIND LIMITING REAGENT:

CO: $V = 50.0\ L$ $T = 25°C = 298.2\ K$ $P = 1.00\ bar$

$n_{CO} = \frac{PV}{RT} = \frac{(1.00\ bar)(50.0\ L)}{(0.08314\ bar\cdot L\cdot K^{-1}mol^{-1})(298.2\ K)} = 2.017\ mol = n_{CO_2}$

O_2: ∵ T, V SAME AS FOR CO

$P = P_T - P_{CO} = 3.26\ bar - 1.00\ bar = 2.26\ bar$

$\frac{V}{RT} = \frac{n_{CO}}{P_{CO}} = \frac{n_{O_2}}{P_{O_2}}$ $\therefore n_{O_2} = \frac{P_{O_2} n_{CO}}{P_{CO}} = \frac{(2.26\ bar)(2.017\ mol)}{1.00\ bar}$
$= 4.559\ mol$

→ THIS WOULD PRODUCE $n_{O_2} \times \frac{1\ mol\ CO_2}{\frac{1}{2}\ mol\ O_2} = 9.12\ mol$

∴ CO IS LIMITING

∴ AFTER REACTION, $P_{CO} = 0$, $P_{CO_2} = 1.00\ bar$

⑥

ACCORDING TO REACTION STOICHIOMETRY,

$n_{O_2,REACTED} = n_{CO,REACTED} \times \frac{\frac{1}{2}\ mol\ O_2}{1\ mol\ CO} = 1.00\ bar \times \frac{1}{2} = 0.500$

$\therefore n_{O_2,REMAINING} = n_{O_2,INITIAL} - n_{O_2,REACTED} = 2.26\ bar - 0.500\ bar$
$= 1.76\ bar$

Question 4. (Chapter 1 lecture, slide 32, Chapter 2 lecture, slide 21)
Elemental analysis of an organic compound gives the following elemental mass percentages: H, 7.068 %; C, 53.48 %; N, 8.913 % and O, 30.54 %. Vapourization of 224 mg of the compound in a 250-mL bulb at 113 °C gives a pressure of 68.61 Torr. What is the molecular formula of the compound?

$m = 224\ mg = 0.224\ g \quad V = 250\ mL = 0.250\ L$

$T = 113°C = (113 + 273.15)K = 386.15\ K \quad p = 68.61\ Torr$

$$n = \frac{m}{M} = \frac{pV}{RT} \quad \therefore M = \frac{mRT}{pV} = \frac{(0.224g)(8.314\ L\cdot kPa\cdot K^{-1}mol^{-1})(386.15K)}{(68.61\ Torr)\left(\frac{101.325kPa}{760\ Torr}\right)(0.250\ L)}$$

$$= 314.5\ g/mol$$

FOR A 100 g SAMPLE:

$$n_H = \frac{m}{M} = \frac{7.068\ g}{1.008\ g/mol} = 7.0119\ mol$$

$$n_C = \frac{53.48g}{12.01\ g/mol} = 4.4530\ mol$$

$$n_N = \frac{8.913g}{14.01\ g/mol} = 0.63619\ mol$$

$$n_O = \frac{30.54g}{16.00\ g/mol} = 1.9088\ mol$$

$\therefore$ EMPIRICAL FORMULA IS

$$C_{\frac{4.4530}{0.63619}} H_{\frac{7.0119}{0.63619}} N_{\frac{0.63619}{0.63619}} O_{\frac{1.9088}{0.63619}}$$

$C_7H_{11}NO_3$

$$M_{C_7H_{11}NO_3} = (7\times 12.01 + 11\times 1.008 + 14.01 + 3\times 16.00)$$

$$= 157.17\ g/mol$$

TO MAKE $M = 314.5\ g/mol$ WE MUST MULTIPLY COEFFICIENTS BY

$$\frac{M_{UNKNOWN}}{M_{C_7H_{11}NO_3}} = 2$$

$\therefore$ MOLECULAR FORMULA IS $C_{14}H_{22}N_2O_6$

(6)

Question 6.
Consider two gas bulbs of equal volume, one filled with CH_4 gas at 4.17 °C and 3.43 bar, the other containing F_2 gas at 50.2 °C and 4.23 bar.

277.32 K

323.35 K

a) Which bulb has more molecules? How much more?

$$n = \frac{pV}{RT} = \frac{N}{N_A} \quad \therefore N = \frac{pV}{RT}N_A$$

$$\frac{N_{CH_3}}{N_{F_2}} = \frac{\frac{p_{CH_4}V_{CH_4}N_A}{RT_{CH_4}}}{\frac{p_{F_2}V_{F_2}N_A}{RT_{F_2}}} = \frac{p_{CH_4}T_{F_2}}{p_{F_2}T_{CH_4}} = \frac{(3.43bar)(323.35K)}{(4.23bar)(277.32K)}$$

$$= 0.945$$

$\because \frac{N_{CH_4}}{N_{F_2}} < 0 \quad \therefore N_{CH_4} < N_{F_2}$

(2)

b) Which bulb has more mass? How much more?

$$n = \frac{m}{M} = \frac{pV}{RT}$$

$$\therefore \frac{m_{CH_4}}{m_{F_2}} = \frac{p_{CH_4} T_{F_2} M_{CH_4}}{p_{F_2} T_{CH_4} M_{F_2}} = (0.945)\left(\frac{12.01 + 4\times1.008}{2\times19.00}\right)$$

$$= 0.399$$

$$\because \frac{m_{CH_4}}{m_{F_2}} < 0 \quad \therefore m_{CH_4} < m_{F_2}$$ (2)

c) Which bulb has more average kinetic energy?

$$\bar{E} = \frac{3RT}{2N_A}$$

$$\therefore \frac{\bar{E}_{CH_4}}{\bar{E}_{F_2}} = \frac{T_{CH_4}}{T_{F_2}} = \frac{277.32K}{323.35K} = 0.85$$

$$\because \frac{\bar{E}_{CH_4}}{\bar{E}_{F_2}} < 0 \quad \therefore \bar{E}_{CH_4} < \bar{E}_{F_2}$$ (2)

d) Average molecular speed?

$$\bar{v} = \sqrt{\frac{3RT}{M}}$$ (3R: CONSTANTS)

$$\frac{\bar{v}_{CH_4}}{\bar{v}_{F_2}} = \sqrt{\frac{T_{CH_4} M_{F_2}}{T_{F_2} M_{CH_4}}}$$

$$= \sqrt{0.85\times\left(\frac{2\times19.00}{12.01+4\times1.008}\right)} = 1.42$$ (2)

$\therefore \bar{v}_{CH_4}$ IS LARGER THAN $\bar{v}_{F_2}$

Question 5.

A 0.155 g mixture of $KClO_3$ and a catalyst was placed in a quartz tube and heated vigorously to drive off all the oxygen as O_2. The O_2 was collected at 20.3°C and a pressure of 743 Torr. The volume of gas collected was 33.8 ml.

a) How many moles of O_2 were produced?

$T = 20.3°C = 293.45 K$ $\quad P = 743$ Torr $\quad V = 33.8 mL = 0.0338 L$

760 Torr $= 101.325$ kPa

$$n = \frac{PV}{RT} = \frac{(743 \text{ Torr})\left(\frac{101.325 \text{ kPa}}{760 \text{ Torr}}\right)(0.0338 L)}{(0.08314 \text{ kPa} \cdot L \cdot K^{-1} mol^{-1})(293.45 K)}$$

$$= 0.001372 \text{ mol}$$

(2)

b) How many moles of KClO3 was in the original mixture?

$$KClO_3 \longrightarrow KCl_{(s)} + \frac{3}{2}O_{2(g)}$$

$$\therefore n_{KClO_3} = n_{O_2} \times \frac{1 \text{ mol } KClO_3}{\frac{3}{2} \text{ mol } O_2}$$

$$= 9.149 \times 10^{-4} \text{ mol}$$

(2)

c) What was the mass percent of $KClO_3$ in the original mixture?

$$\text{MASS \%}_{KClO_3} = \frac{m_{KClO_3}}{m_{TOTAL}} = \frac{n_{KClO_3} M_{KClO_3}}{m_{TOTAL}} \times 100\%$$

$$= \frac{(9.149 \times 10^{-4} \text{ mol})(39.10 + 35.45 + 3 \times 16.00)\frac{g}{mol}}{0.155 g} \times 100\%$$

$$= 72.3\%$$

(2)