Chemistry 1105 Spring 2024 Test 3

Thursday, March 28, 2024

Time: 1 hour 50 minutes

Name: ANSWERS

Student #: _____

*This test consists of **eight** pages of questions, a page of useful constants and conversions, and a periodic table. Please ensure that you have a complete test and, if you do not, obtain one from me **immediately**. There are **35** marks available. Good luck!*

1) **[3 marks]** At 100 torr pressure and 90.46°C, the density of a gas of formula H_2O_n is 0.150 g/L. What is the number, n?

$$MM = \frac{(0.15)(62.36359822)(363.61)}{100} = 34.014\ldots \frac{g}{mol}$$

$$2(1.0079) + n(15.999) = 34.014\ldots \Rightarrow \boxed{n = 2}$$

2) **[4 marks]** A mixture of two gases (A and B) had a total pressure of 60 atm. There were three moles of gas A, and the mole fraction of gas B was found to be 0.75.

a) How many moles of gas B were in the mixture?

$$X_A = 0.25$$

$$\frac{3}{n_{TOT}} = 0.25 \Rightarrow n_{TOT} = 12, \text{ so } \boxed{n_B = 9}$$

b) What were the partial pressures of each gas?

$$P_A = 0.25(60) = 15 \text{ atm}$$

$$P_B = 0.75(60) = 45 \text{ atm}$$

3) **[3 marks]** According to Apple, the iPhone 15 Pro Max can be submerged in 6 metres of water for up to half an hour. If the density of water is 0.9984 g/cm^3, how many bars of pressure is exerted by water at this depth?

$P = D \cdot g \cdot h = 58745.75616\ Pa$

h: $6\ m$

g: $9.80665\ \frac{m}{s^2}$

$58745\ Pa \times \frac{1\ bar}{100{,}000\ Pa} = \boxed{0.587\ bar}$

$0.9984\ \frac{g}{cm^3} \times \frac{1\ kg}{1000\ g} \times \left(\frac{100\ cm}{1\ m}\right)^3 = 998.4\ \frac{kg}{m^3}$

4) **[4 marks]** The following apparatus was assembled:

Flask 1:
Volume: 8 L
Filled with: HCN
At a pressure of: 5 atm

Flask 2:
Volume: 12 L
Filled with: H_2
At a pressure of 7 atm

Both flasks were kept at a temperature of 336.18°C before, during, and after reaction.

When the valve was opened, the following reaction occurred:

$$HCN(g) + 3H_2(g) \longrightarrow CH_4(g) + NH_3(g)$$

Calculate the partial pressures of all species **after** reaction.

$n_{HCN} = \frac{5 \cdot 8}{RT} = \frac{40}{RT}$ $n_{H_2} = \frac{7 \cdot 12}{RT} = \frac{84}{RT}$

LR check:

$\frac{40}{RT}$ moles HCN $\times \frac{1 \text{ rxn}}{1 \text{ HCN}} = \frac{40}{RT}$ moles rxn

$\frac{84}{RT}$ moles $H_2 \times \frac{1 \text{ rxn}}{3 H_2} = \frac{28}{RT}$ moles rxn

LR

HCN L.O. : $\frac{40}{RT}$ moles HCN $- \frac{84}{RT}$ moles $H_2 \times \frac{1 \text{ HCN}}{3 H_2} = \frac{12}{RT}$

CH_4 (and NH_3) made: $\frac{84}{RT}$ moles $H_2 \times \frac{1 CH_4}{3 H_2} = \frac{28}{RT}$ moles CH_4

$P_{HCN} = \frac{\frac{12}{RT} \times RT}{20} = 0.6$ atm $P_{NH_3} = P_{CH_4} = \frac{\frac{28}{RT} \times RT}{20} = 1.4$ atm

$P_{H_2} = 0$

5) **[4 marks]** A 3-mole piece of iron ($\bar{C} = 25.07 \frac{J}{mol \cdot °C}$) at 89.35°C was placed into 200 g of water ($S = 4.184 \frac{J}{(g \cdot °C)}$ at 15°C. The water was contained in a cup with $C = 20 \frac{J}{°C}$. What was the final temperature of the water?

$$q_{Fe} = 3 \text{ moles} \times 25.07 \frac{J}{mol \cdot °C} \times (T - 89.35)°C$$

$$+ q_{H_2O} = 200 g \times 4.184 \frac{J}{g \cdot °C} \times (T - 15)°C$$

$$+ q_{cup} = 20 \frac{J}{°C} (T - 15)°C$$

$$0 J$$

$$75.21(T - 89.35) + 836.8(T - 15) + 20(T - 15) = 0$$

$$75.21T - 6720.0135 + 836.8T - 12552 + 20T - 300 = 0$$

$$932.01T - 19572.0135 = 0$$

$$\Rightarrow T = 20.99978917 \approx 21°C$$

6) **[4 marks]** A 760.9-mg piece of $Ca(OH)_2$ (74.09 g/mol) was put into 100.0 mL of 0.300 M HCl (1.00 g/mL, 4.184 $\frac{J}{(g \cdot °C)}$) at 22.85°C:

$2HCl(aq) + Ca(OH)_2(s) \longrightarrow CaCl_2(aq) + 2H_2O(l)$

The temperature of the solution increased to 26.65°C. Calculate the molar enthalpy of the reaction.

$q_{HCl} = (100\ mL \times 1.00\ \frac{g}{mL} + 0.7609\ g) \times 4.184\ \frac{J}{g \cdot °C} \times (26.65 - 22.85)$

$= 1602.\ldots\ J$

$+q_{rxn} = -1602.\ldots\ J$

$0\ J$

LR check:

$0.7609\ g\ Ca(OH)_2 \times \frac{1\ mol}{74.09\ g} \times \frac{1\ rxn}{1\ Ca(OH)_2} = 0.010\ldots\ mol\ rxn$

$100 \times 10^{-3}\ L \times \frac{0.3\ mol\ HCl}{1\ L} \times \frac{1\ rxn}{2\ HCl} = 0.015\ mol\ rxn$

$\therefore\ 0.010\ldots\ mol\ rxn = -1602\ldots\ J$

or

$1\ mol\ rxn = -155990.9206\ldots\ J$

$(\simeq -156\ kJ)$

7) **[3 marks]** Given the following reactions:

$SrO(s) + CO_2(g) \longrightarrow SrCO_3(s)$ $\quad \Delta H = -234$ kJ

$2SrO(s) \longrightarrow 2Sr(s) + O_2(g)$ $\quad \Delta H = +1184$ kJ

$2SrCO_3(s) \longrightarrow 2Sr(s) + 2C(s, gr) + 3O_2(g)$ $\quad \Delta H = +2440$ kJ

Find ΔH for the following reaction:

$C(s, gr) + O_2(g) \longrightarrow CO_2(g)$

$Sr(s) + C(s,gr) + 1.5O_2(g) \longrightarrow SrCO_3(s)$ $\quad \Delta H = -1220$ kJ

~~$2Sr(s) + O_2(g) \longrightarrow 2SrO(s)$~~ ~~$\Delta H = +1184$ kJ~~

$SrO(s) \longrightarrow Sr(s) + \frac{1}{2}O_2(g)$ $\quad \Delta H = +592$ kJ

$SrCO_3(s) \longrightarrow SrO(s) + CO_2(g)$ $\quad \Delta H = +234$ kJ

$C(s, gr) + O_2(g) \longrightarrow CO_2(g)$ $\quad \Delta H = -394$ kJ

8) **[1 mark]** What is the molar enthalpy of formation of SrO(s)?

−592 kJ

9) **[4 marks]** Given the reaction:

$2Sr(s) + 2C(s, gr) + 3O_2(g) \longrightarrow 2SrCO_3(s) \qquad \Delta H = -2440\ kJ$

How many kJ of heat would be released by the reaction of 87.62 grams of Sr with 31.998 grams of oxygen and 12.011 grams of C(s, gr)?

LR check:

$$87.62\,g\ Sr \times \frac{1\ mol}{87.62\,g} \times \frac{1\ rxn}{2\ Sr} = 0.5\ moles\ rxn$$

$$31.998\,g\ O_2 \times \frac{1\ mol}{31.998\,g} \times \frac{1\ rxn}{3\ O_2} = 0.\bar{3}\ mol\ rxn \quad \text{(LR)}$$

$$12.011\,g\ C \times \frac{1\ mol}{12.011\,g} \times \frac{1\ rxn}{2\ C} = 0.5\ moles\ rxn$$

$$0.\bar{3}\ moles\ rxn \times \frac{-2440\ kJ}{1\ mole\ rxn} = -813.\bar{3}\ kJ$$

So 813.$\bar{3}$ kJ of heat would be released.

10) **[4 marks]** Given the following equilibrium:

$H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$ $\Delta H° < 0$ (exothermic)

Predict the effect that each of the changes given below would have on the value of K and on the moles of Cl_2 present in a fresh system initially at equilibrium. Your choices are **I**ncrease from the starting value, **D**ecrease from the starting value, or **N**ot **C**hange from the starting value. You may assume that, unless explicitly stated otherwise, the changes were carried out at constant temperature.

	Effect on:					
	K			Cl_2		
Adding some H_2	I	D	NC	I	D	NC
Cooling the reaction mixture	I	D	NC	I	D	NC
compressing the reaction mixture	I	D	NC	I	D	NC
Adding a non-reactive gas	I	D	NC	I	D	NC

11) **[1 mark]** Write a reaction for which the equilibrium expression is $K = [O_2]$.

There are many possibilities. One is $O_2(\ell) \rightleftharpoons O_2(g)$