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Chemistry 1154 R25 Fall 2023 Test 2

Friday, October 27, 2023 Time: 1 hour 50 minutes

Name: ANSWERS Student #: ______________________

*This test consists of **seven** pages of questions, the formula sheet, and a periodic table. Please ensure that you have a complete test and, if you do not, obtain one from me **immediately**. There are **42** marks available. Good luck!*

1) **[4 marks]** The following apparatus was assembled:

Flask 1:
Volume: 4 litres
Filled with: C_4H_{10}
At a pressure of: 6000 torr

Flask 2:
Volume: 6 litres
Filled with: O_2
At a pressure of: 6500 torr

The two flasks were kept at a temperature of 528.6°C. The flasks were connected to one another by a valve (of no significant volume). When the valve was opened, the reaction

$$2C_4H_{10}(g) + 13O_2(g) \longrightarrow 8CO_2(g) + 10H_2O(g)$$

occurred. Calculate the mole fractions of all species after reaction. Give your answers in torr.

$n_{C_4} = \frac{6000 \times 4}{RT} = \frac{24000}{RT}$; $n_{O_2} = \frac{6500 \times 6}{RT} = \frac{39000}{RT}$

LR check:

$\frac{24000}{RT}$ moles $C_4 \times \frac{1 \text{ rxn}}{2C_4} = \frac{12,000}{RT}$ mols rxn ; LR $\frac{39,000}{RT}$ moles $O_2 \times \frac{1 \text{ rxn}}{13O_2} = \frac{3,000}{RT}$ mols rxn

C_4 L.O.: $\frac{24,000}{RT} - \frac{39,000}{RT}$ mols $O_2 \times \frac{2C_4}{13O_2} = \frac{18,000}{RT}$; $n_{O_2} = 0$

CO_2: $\frac{39,000}{RT}$ mols $O_2 \times \frac{8CO_2}{13O_2} = \frac{24,000}{RT}$ moles CO_2

H_2O: $\frac{39,000}{RT}$ moles $O_2 \times \frac{10H_2O}{13O_2} = \frac{30,000}{RT}$

total is $\frac{72,000}{RT}$

$X_{O_2} = 0$; $X_{C_4} = \frac{\frac{18,000}{RT}}{\frac{72,000}{RT}} = \frac{1}{4}$; $X_{CO_2} = \frac{\frac{24,000}{RT}}{\frac{72,000}{RT}} = \frac{1}{3}$; $X_{H_2O} = \frac{\frac{30,000}{RT}}{\frac{72,000}{RT}} = \frac{5}{12}$

2) **[4 marks]** Helium effuses 5.0512 times faster than a gas of formula S_nF_m, and 5.9167 times faster than a gas of formula S_nF_{m+n}. What are the formulas of the two gases?

$$M_1 = 4.0026(5.0512)^2 = 102.12\ldots$$
$$M_2 = 4.0026(5.9167)^2 = 140.12\ldots$$

SO:

$$n(32.065) + m(18.998) = 102.12\ldots \quad (1)$$
$$n(32.065) + (m+n)(18.998) = 140.12\ldots$$
$$\hookrightarrow n(32.065) + m(18.998) + n(18.998) = 140.12\ldots$$
$$\hookrightarrow n(51.063) + 18.998m = 140.12\ldots \quad (2)$$

(2) - (1) gives

$$18.998n = 37.995\ldots$$
$$\Rightarrow n = 2$$

And, from (1):

$$2(32.065) + m(18.998) = 102.12\ldots$$
$$\Rightarrow m = 2$$

$$\boxed{\text{So the gases are } S_2F_2 \text{ and } S_2F_4}$$

3) **[4 marks]** Given the following equilibrium:

$N_2(g) + 3I_2(s) \rightleftharpoons 2NI_3(s)$ $\Delta H° > 0$

Predict the effect that each of the changes given below would have on the value of K_p and on the moles of I_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_p			I_2		
Adding some N_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 some $NI_3(s)$	I	D	[✓ NC]	I	D	[✓ NC]

4) **[6 marks total]** For the reaction:

$C_2H_4(g) + H_2(g) \rightleftharpoons C_2H_6(g)$ $\Delta H° = -136.4$ kJ and $K_p = 4.05 \times 10^{17}$ @ 25°C

a) **[2 marks]** K_p for the reaction:

$\frac{1}{2}C_2H_6(g) \rightleftharpoons \frac{1}{2}C_2H_4(g) + \frac{1}{2}H_2(g)$

at 25°C will be:

i) 4.94×10^{-18} [✓ ii) 1.57×10^{-9}]   iii) -6.36×10^{8} iv) -2.03×10^{17}

b) **[2 marks]** K_c at 25°C will be:

i) 1.63×10^{14} ii) 1.63×10^{16} [✓ iii) 1.00×10^{19}]   iv) 1.00×10^{21}

c) **[2 marks]** K_p at 30°C will be:

i) 1.56×10^{-22} ii) 1.29×10^{-30} [✓ iii) 1.63×10^{17}]   iv) 4.05×10^{17}

5) **[2 marks]** The normal boiling point of ethanol is 78.35°C, and its enthalpy of vaporization is 42.3 kJ/mol. Its vapour pressure (in torr) at 35°C will be:

a) 2.8×10^{-86} b) 9×10^{-33} [✓ c) 99.2] d) 758.5

6) **[4 marks]** A flask was charged with 4 bar of CH_4, 1 bar of C_4H_{10}, and 3 bar of H_2, and the equilibrium:

$4CH_4(g) \rightleftharpoons C_4H_{10}(g) + 3H_2(g)$ $K_p = 1.0547 \times 10^{-5}$

established. Calculate the equilibrium partial pressures of all species.

$4CH_4 \rightleftharpoons C_4H_{10} + 3H_2$ $Q = \frac{3^3}{4^4} = 0.105\ldots$

too big, rxn ←

	$4CH_4$	C_4H_{10}	$3H_2$
i	4	1	3
C	+4X	−X	−3X
e	4+4X (=4(1+x))	1−X	3−3X (=3(1−x))

$$\frac{(1-x)(3(1-x))^3}{(4(1+x))^4} = 1.0547\times10^{-5}$$

$$\frac{27(1-x)^4}{256(1+x)^4} = 1.0547\times10^{-5}$$

$$\frac{(1-x)^4}{(1+x)^4} = 1.0547\times10^{-5} \times \frac{256}{27} = 1.0\ldots\times10^{-4}$$

$$\frac{(1-x)}{(1+x)} = 0.100\ldots \quad (=a)$$

$1-x = a + ax$

$1-a = ax + x$

$x = \frac{1-a}{1+a} = 0.818\ldots$

So:

$$\boxed{\begin{array}{l} P_{CH_4,e} = 7.727\ldots \text{ bar} \\ P_{C_4H_{10},e} = 0.1818\ldots \text{ bar} \\ P_{H_2,e} = 0.545\ldots \text{ bar} \end{array}}$$

7) **[3 marks]** Only 7.761 × 10⁻⁴ grams of BiI_3 (bismuth iodide, 589.69 g/mol) will dissolve in 100 mL of water. What is the K_{sp} of BiI_3?

molar solubility
↓

$$\frac{7.761\times10^{-4}\,g \times \frac{1\,mol}{589.69\,g}}{0.1\,L} = 1.316\times10^{-5}\,M$$

$BiI_3 \rightleftharpoons Bi^{2+} + 3I^-$

	BiI_3	Bi^{2+}	$3I^-$
i	/	0	0
c	Let x moles dissolve in 1L.	+x	+3x
e		x	3x

$K_{sp} = x(3x)^3$

$= 27x^4$

$= \boxed{8.1\times10^{-19}}$

8) **[3 marks]** The K_{sp} of $Cd(CN)_2$ is 9.6 x 10⁻⁹. Calculate the molar solubility of $Cd(CN)_2$ in a 0.20 M solution of KCN.

$Cd(CN)_2 \rightleftharpoons Cd^{2+} + 2CN^-$

	$Cd(CN)_2$	Cd^{2+}	$2CN^-$
i		0	0.2
c		+x	+2x
e		x	0.2+2x

$x(0.2+\cancel{2x})^2 = 9.6\times10^{-9}$

↑
small

$\boxed{x = 2.4\times10^{-7}\,M}$

9) **[3 marks]** A solution has $[CO_3^{2-}] = 0.0030$ M and $[PO_4^{3-}] = 0.0020$ M. To separate these two ions, you slowly add solid $CaCl_2$ into the solution. The K_{sp}s of $CaCO_3$ and $Ca_3(PO_4)_2$ are 2.8×10^{-9} and 2.0×10^{-29}, respectively. At the point of maximum separation, what percent of the first anion to precipitate will remain in solution?

$[CO_3^{2-}]$: $[Ca^{2+}]_e(3\times10^{-3}) = 2.8\times10^{-9}$; $[Ca^{2+}] = 9.3\times10^{-7}$

$[PO_4^{3-}]$: $[Ca^{2+}]_e^3(2\times10^{-3})^2 = 2.0\times10^{-29}$; $[Ca^{2+}] = 1.71\times10^{-8}$

↑

First to PPT.

$(9.33..\times10^{-7})^3\cdot[PO_4^{3-}]_e^2 = 2.0\times10^{-29}$

$\Rightarrow [PO_4^{3-}]_e = 4.96\times10^{-6}$ M

$$\frac{4.96\times10^{-6}}{2\times10^{-3}}\times100 = \boxed{0.248\%}$$

10) **[2 marks]** The pH of a certain aqueous solution is 7.10. The solution is:

a) Acidic
b) Neutral
c) Basic
[✓ d)] There is not enough information to answer this question.

11) **[2 marks]** The pH of a 1.00×10^{-9} M solution of $Mg(OH)_2$ at 25°C should be:

a) 5.0
b) 5.3
[✓ c)] 7.0
d) 8.7
e) 9.0

12) **[5 marks total]** HN_3 (hydrozoic acid) is a weak acid with a $K_a = 1.9 \times 10^{-5}$. Calculate the pH of the following solutions:

a) **[2 marks]** 0.0526 M hydrazoic acid

$$HN_3 \rightleftharpoons H^+ + N_3^-$$

	HN_3	H^+	N_3^-
i	0.0526	0	0
c	$-x$	$+x$	$+x$
e	0.0526	x	x

$$\frac{x^2}{0.0526-\cancel{x}} = 1.9\times10^{-5}$$

small

$$x = [H^+]_e = 1\times10^{-3};\ pH = \boxed{3.0}$$

b) **[3 marks]** A solution that has $[HN_3] = 0.10$ M and $[NaN_3] = 0.19$ M

$$HN_3 \rightleftharpoons H^+ + N_3^-$$

	HN_3	H^+	N_3^-
i	0.1	0	0.19
c	$-x$	$+x$	$+x$
e	$0.1-x$	x	$0.19+x$

$$\frac{x(0.19\cancel{+x})}{(0.1-\cancel{x})} = 1.9\times10^{-5}$$

small

$$\Rightarrow x = [H^+]_e = 1.0\times10^{-5};\ pH = \boxed{5.0}$$