

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 $528.6^\circ C$. The flasks were connected to one another by a valve (of no significant volume). When the valve was opened, the reaction



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

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

LR check:

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

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

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

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

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

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

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?

$$M_1 = 4,0026 (5,0512)^2 = 102,12 \dots$$

$$M_2 = 4,0026 (5,9167)^2 = 140,12 \dots$$

So:

$$n(32,065) + m(18,998) = 102,12 \dots \quad (1)$$

$$n(32,065) + (m+n)(18,998) = 140,12 \dots$$

$$\rightarrow n(32,065) + m(18,998) + n(18,998) = 140,12 \dots$$

$$\rightarrow n(51,063) + 18,998m = 140,12 \dots \quad (2)$$

(2) - (1) gives

$$18,998n = 37,995 \dots$$

$$\Rightarrow n = 2$$

And, from (1):

$$2(32,065) + m(18,998) = 102,12 \dots$$

$$\Rightarrow m = 2$$

So the gases are S_2F_2 and S_2F_4

3) [4 marks] Given the following equilibrium:



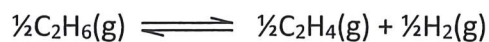
Predict the effect that each of the changes given below would have on the value of K_p and on the moles of I_2 present in a fresh system initially at equilibrium. Your choices are Increase from the starting value, Decrease from the starting value, or Not Change from the starting value. You may assume 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 $\text{NI}_3(\text{s})$	I	D	NC	I	D	NC

4) [6 marks total] For the reaction:



a) [2 marks] K_p for the reaction:



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:

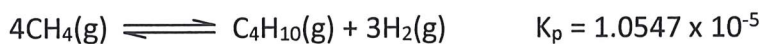
a) 2.8×10^{-86}

b) 9×10^{-33}

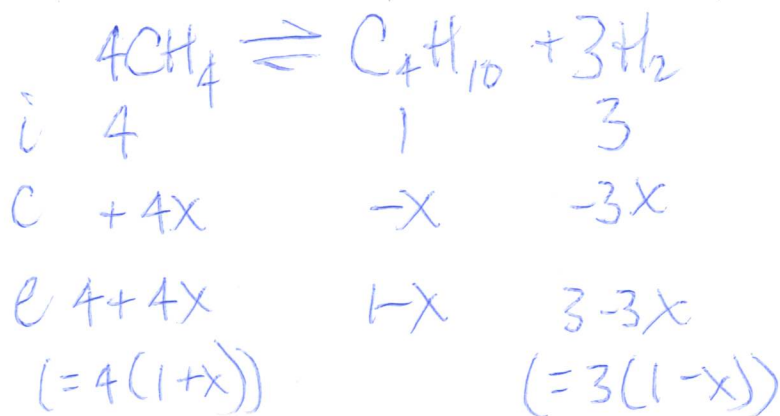
c) 99.2

d) 758.5

6) [4 marks] A flask was charged with 4 bar of CH₄, 1 bar of C₄H₁₀, and 3 bar of H₂, and the equilibrium:



established. Calculate the equilibrium partial pressures of all species.



$Q = \frac{3^3}{4^4} = 0.105...$
 too big, rxn ←

$$\frac{(1-x)(3(1-x))^3}{(4(1+x))^4} = 1.0547 \times 10^{-5}$$

$$\frac{27(1-x)^4}{256(1+x)^4} = 1.0547 \times 10^{-5}$$

$$\frac{(1-x)^4}{(1+x)^4} = 1.0547 \times 10^{-5} \times \frac{256}{27}$$

$$\frac{(1-x)^4}{(1+x)^4} = 1.0... \times 10^{-4} \times \frac{256}{27}$$

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

$$1-x = a+ax$$

$$1-a = ax+x$$

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

$$= 0.818...$$

So:

$P_{\text{CH}_4, \text{e}} = 7.727... \text{ bar}$

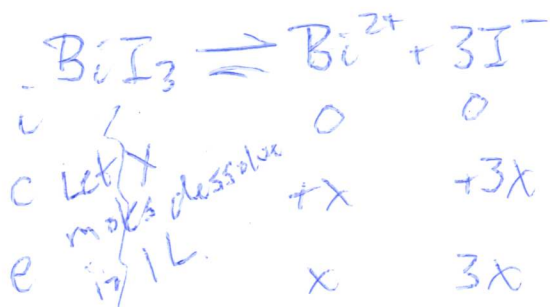
$P_{\text{C}_4\text{H}_{10}, \text{e}} = 0.1818... \text{ bar}$

$P_{\text{H}_2, \text{e}} = 0.545... \text{ bar}$

- 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 ?

$$\frac{7.761 \times 10^{-4} \text{ g} \times \frac{1 \text{ mol}}{589.69 \text{ g}}}{0.1 \text{ L}} = 1.316 \times 10^{-5} \text{ M}$$

molar solubility
↓

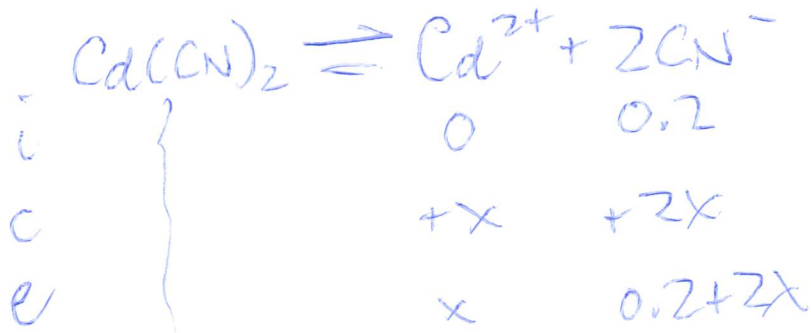


$$K_{sp} = x(3x)^3$$

$$= 27x^4$$

$= 8.1 \times 10^{-19}$

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



$$x(0.2 + 2x)^2 = 9.6 \times 10^{-9}$$

↑
small

$x = 2.4 \times 10^{-7} \text{ M}$

- 9) [3 marks] A solution has $[\text{CO}_3^{2-}] = 0.0030 \text{ M}$ and $[\text{PO}_4^{3-}] = 0.0020 \text{ M}$. To separate these two ions, you slowly add solid CaCl_2 into the solution. The K_{sp} s of CaCO_3 and $\text{Ca}_3(\text{PO}_4)_2$ 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?

$$[\text{CO}_3^{2-}]: [\text{Ca}^{2+}]_e (3 \times 10^{-3}) = 2.8 \times 10^{-9}; [\text{Ca}^{2+}] = 9.3 \times 10^{-7}$$

$$[\text{PO}_4^{3-}]: [\text{Ca}^{2+}]_e^3 (2 \times 10^{-3})^2 = 2.0 \times 10^{-29}; [\text{Ca}^{2+}] = 1.71 \times 10^{-8}$$

↑
First to PPT.

$$(9.33 \times 10^{-7})^3 \cdot [\text{PO}_4^{3-}]_e^2 = 2.0 \times 10^{-29}$$

$$\Rightarrow [\text{PO}_4^{3-}]_e = 4.96 \times 10^{-6} \text{ M}$$

$$\frac{4.96 \times 10^{-6}}{2 \times 10^{-3}} \times 100 = \boxed{0.248\%}$$

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

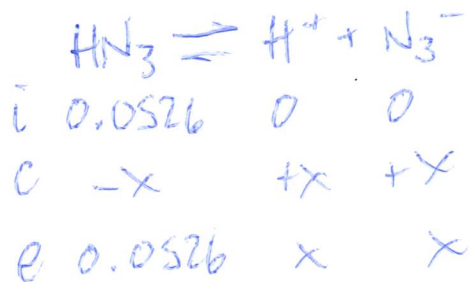
- a) Acidic
- b) Neutral
- c) Basic
- d) There is not enough information to answer this question.

- 11) [2 marks] The pH of a $1.00 \times 10^{-9} \text{ M}$ solution of $\text{Mg}(\text{OH})_2$ 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 (hydrazoic 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

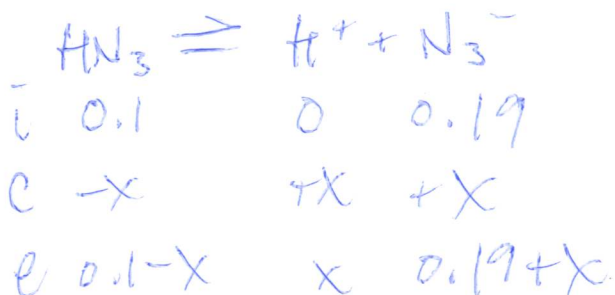


$$\frac{x^2}{0.0526 - x} = 1.9 \times 10^{-5}$$

↑
small

$$x = [\text{H}^+]_e = 1 \times 10^{-3}; \text{pH} = \boxed{3.0}$$

b) [3 marks] A solution that has $[\text{HN}_3] = 0.10 \text{ M}$ and $[\text{NaN}_3] = 0.19 \text{ M}$



$$\frac{x(0.19+x)}{(0.1-x)} = 1.9 \times 10^{-5}$$

↑
small

$$\Rightarrow x = [\text{H}^+]_e = 1.0 \times 10^{-5}; \text{pH} = \boxed{5.0}$$