

Chemistry 1154 Spring 2011 test 2

Wednesday, February 23, 2011

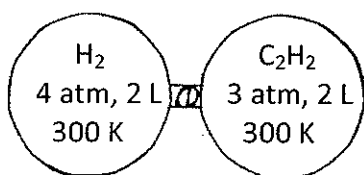
Time: 1 hour 50 minutes

Name: ANSWERS

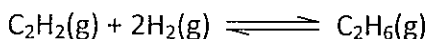
Student number: _____

This test consists of *nine* pages of questions, the formula sheet, and a periodic table. Please ensure you have a complete paper and, if you do not, obtain one from me immediately. There are 45 marks available. Good luck!

1) [3 marks] The following apparatus was assembled:



When the valve was opened, the following reaction occurred:



What were the partial pressures of all species after reaction?

$$n_{\text{H}_2} = \frac{8}{RT} ; n_{\text{C}_2\text{H}_2} = \frac{6}{RT}$$

LR check:

$$\frac{8}{RT} \text{ moles H}_2 \times \frac{1 \text{ rxn}}{2 \text{ H}_2} = \frac{4}{RT} \text{ moles rxn} ; \frac{6}{RT} \text{ moles C}_2\text{H}_2 \times \frac{1 \text{ rxn}}{1 \text{ C}_2\text{H}_2} = \frac{6}{RT} \text{ moles rxn}$$

$\therefore \text{H}_2$ limits; $P_{\text{H}_2} = 0$ after rxn.

$$\text{C}_2\text{H}_2 \text{ L.O. : } \frac{6}{RT} \text{ moles C}_2\text{H}_2 - \frac{8}{RT} \text{ moles H}_2 \times \frac{1 \text{ C}_2\text{H}_2}{2 \text{ H}_2} = \frac{2}{RT} \text{ moles C}_2\text{H}_2$$

$$\text{C}_2\text{H}_6 \text{ made: } \frac{8}{RT} \text{ moles H}_2 \times \frac{1 \text{ C}_2\text{H}_6}{2 \text{ H}_2} = \frac{4}{RT} \text{ moles C}_2\text{H}_6$$

$$P_{\text{C}_2\text{H}_2} = \frac{2}{RT} \times RT = 0,5 \text{ atm. } P_{\text{C}_2\text{H}_6} = 1 \text{ atm; } P_{\text{H}_2} = 0$$

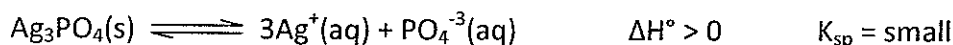
- 2) [1 mark] "Mystery Gas X" has a density of 2.449 g/L at 100°C and 0.750 atm pressure. What is the molar mass of "Mystery Gas X"?

$$MM \times P = D \times R \times T$$

$$\Downarrow$$

$$MM = \frac{D \times R \times T}{P} = \frac{(2.449)(0.0820575)(373.15)}{0.750} = 100 \frac{\text{g}}{\text{mol}}$$

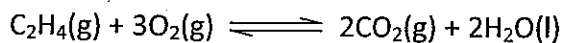
- 3) [4 marks] For the reaction



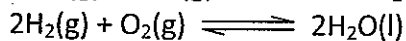
predict the effect that each of the following changes would have on the value of K_{sp} for the equilibrium and the amount of Ag_3PO_4 present. Assume that each change is carried out on a fresh mixture at equilibrium, and that temperature is held constant unless specifically indicated otherwise. Your choices are Increase from the current value, Decrease from the current value, or Not Change the current value. Circle your choice.

	Effect on:					
	$\text{Ag}_3\text{PO}_4(\text{s})$			K_{sp}		
Adding AgNO_3	(I)	D	NC	I	D	(NC)
Heating the reaction mixture	I	(D)	NC	(I)	D	NC
Adding water	I	(D)	NC	I	D	(NC)
Adding NaCl (AgCl is insoluble)	I	(D)	NC	I	D	(NC)

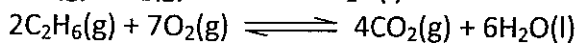
4) [3 marks] Given the equilibria:



$$K_p = 1.0 \times 10^{40}$$

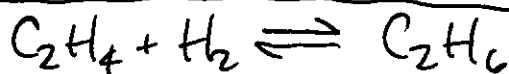
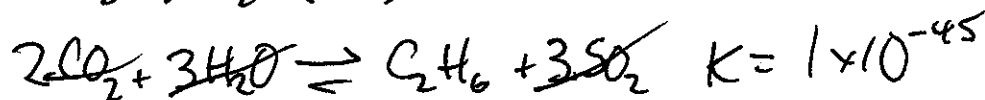
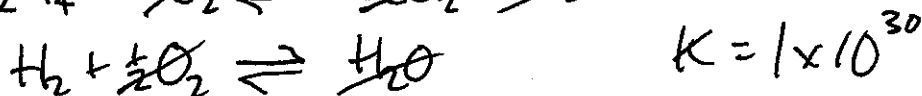
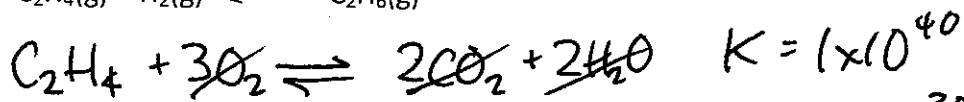
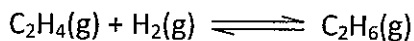


$$K_p = 1.0 \times 10^{60}$$



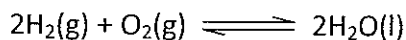
$$K_p = 1.0 \times 10^{90}$$

Calculate K_p for the reaction:



$$K = 1 \times 10^{25}$$

5) [2 marks] Given that the reaction

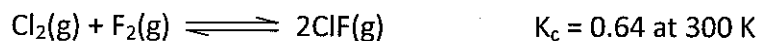


has $K_p = 1.0 \times 10^{60}$ at 25°C , calculate K_c for the reaction at 25°C .

$$1 \times 10^{60} = K_c (0.0820575 \times 298.15)^{-3}$$

$$\Rightarrow K_c = 1.46 \times 10^{64}$$

- 6) [5 marks total] A 2.0-litre flask was charged with 1.0 mol of Cl_2 , 1.0 mol of F_2 , and 0.50 mol of ClF , and the equilibrium



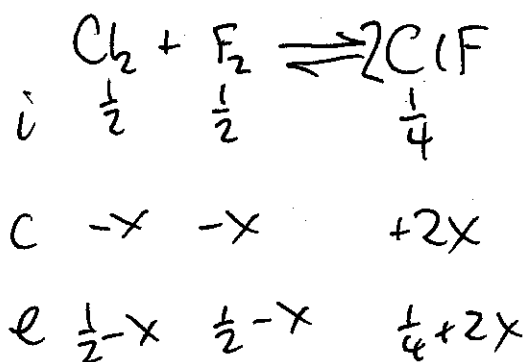
established.

- a) [2 marks] In which direction did the reaction proceed to establish equilibrium? How do you know?

$$Q = \left(\frac{\frac{1}{4}}{\frac{1}{2}} \right)^2 = 0.25$$

$Q < K$, so rxn \rightarrow

- b) [3 marks] What were the equilibrium concentrations of all species (at 300 K) once equilibrium had been attained?



$$\frac{\left(\frac{1}{4}+2x\right)^2}{\left(\frac{1}{2}-x\right)^2} = 0.64$$

$$\frac{\left(\frac{1}{4}+2x\right)}{\left(\frac{1}{2}-x\right)} = 0.8$$

$$\frac{1}{4} - 2x = 0.4 - 0.8x$$

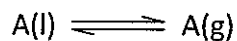
$$2.8x = 0.15$$

$$x = \frac{3}{56}$$

So $[\text{Cl}_2]_e = [\text{F}_2]_e = \frac{25}{56} \text{ M}$
and $[\text{ClF}] = \frac{5}{14} \text{ M}$

(Decimals: 0.446428571 M
 $+ 0.3571428 \text{ M}$)

- 7) [3 marks] The evaporation of a liquid is an equilibrium process. For "Mystery Liquid A" the reaction looks like:



The pressure of the gas in the reaction is called the "vapour pressure" of the liquid, and the value for the enthalpy of reaction is called the "enthalpy of vaporization."

Suppose that the vapour pressure of "Mystery Liquid A" is 100.0 mmHg at 25°C, and the enthalpy of vaporization is 35.0 kJ/mol. What will be the vapour pressure of "Mystery Liquid A" at 75°C? Give your answer in atm.

$$\ln\left(\frac{P_2}{100}\right) = \frac{35000}{8.314472} \left(\frac{50}{\cancel{323.15} \times 298.15} \right)$$

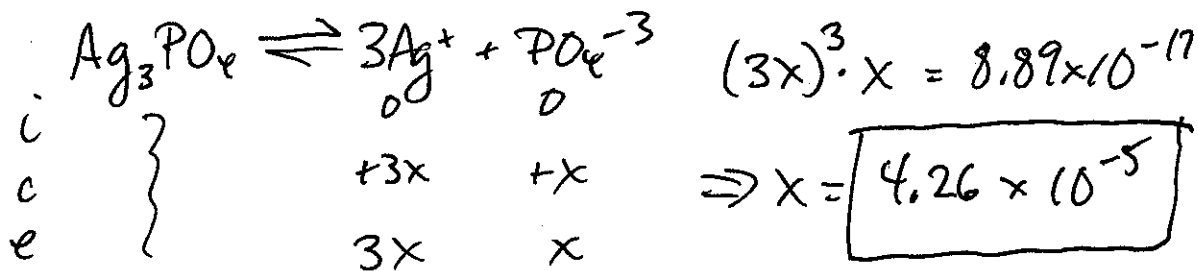
$$= \cancel{2.184562124} 2.02769\dots$$

$$\frac{P_2}{100} = 7.5965\dots$$

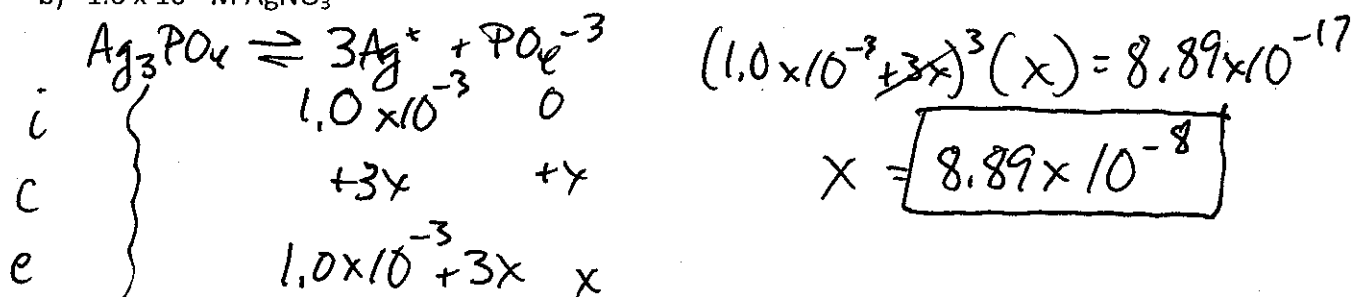
$$P_2 = 760 \text{ mmHg} = \boxed{1 \text{ atm}}$$

8) [4 marks] The K_{sp} of Ag_3PO_4 is 8.89×10^{-17} . Calculate the molar solubility of Ag_3PO_4 in:

a) Water



b) 1.0×10^{-3} M $AgNO_3$



9) [4 marks] A solution has $[Ca^{+2}] = 0.10$ M and $[Ag^+] = 0.020$ M. solid Na_2CO_3 is slowly added to the solution. If the K_{sp} s of $CaCO_3$ and Ag_2CO_3 are 3.36×10^{-9} and 8.46×10^{-12} respectively:

a) Which of Ca^{+2} or Ag^+ will precipitate first?

$$Ca^{2+}: (0.1)x = 3.36 \times 10^{-9} \Rightarrow x = 3.36 \times 10^{-8}$$

$$Ag^+: (0.02)^2 \cdot x = 8.46 \times 10^{-12} \Rightarrow x = 2.115 \times 10^{-8}$$

So Ag^+ precipitates first.

b) At the point of maximum separation, what percent of the first ion to precipitate will remain in solution?

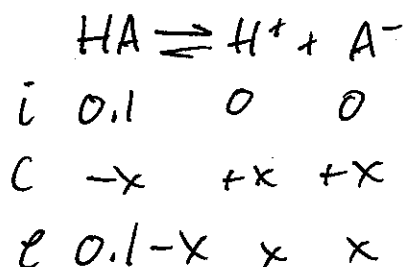
$$[Ag^+]_e^2 \cdot 3.36 \times 10^{-8} = \cancel{3.36 \times 10^{-9}} 8.46 \times 10^{-12}$$

$$\Rightarrow [Ag^+]_e = 0.01587 \text{ M}$$

$$\frac{0.01587}{0.02} \times 100 = \boxed{79.349\%}$$

10) [5 marks total] HA is a weak acid with a $K_a = 1.0 \times 10^{-5}$. Calculate the pH (at 25°C) of the following solutions made using HA:

a) [2 marks] 20.0 mL of 0.10 M HA

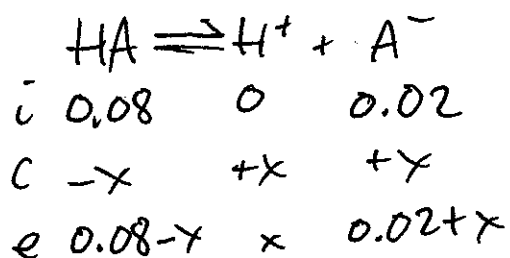


$$\frac{x^2}{0.1-x} = 1 \times 10^{-5} \Rightarrow x = [\text{H}^+]_e = 1 \times 10^{-3} \text{ M}$$

$$\boxed{\text{pH} = 3.0}$$

b) [3 marks] 20.0 mL of 0.10 M HA and 5.0 mL of 0.10 M NaA.

$$[\text{HA}] = \frac{20}{25} \times 0.1 = 0.08 \text{ M} \quad [\text{NaA}] = \frac{5}{25} \times 0.1 = 0.02 \text{ M}$$



$$\frac{x(0.02+x)}{(0.08-x)} = 1 \times 10^{-5}$$

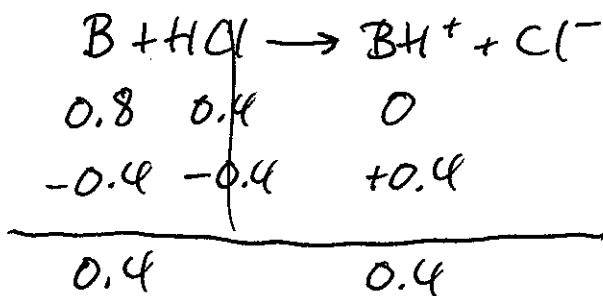
$$x = [\text{H}^+]_e = 4 \times 10^{-5}$$

$$\boxed{\text{pH} = 4.40}$$

11) [5 marks total] B is a weak base with $K_b = 1.0 \times 10^{-4}$. Calculate the pH (at 25°C) of the following solutions made using B:

a) [3 marks] 20.0 mL of 1.0 M B and 5.0 mL of 2.0 M HCl

$$[B] = \frac{20}{25} \times 1 = 0.8 \text{ M} \quad [HCl] = \frac{5}{25} \times 2 = 0.4 \text{ M}$$

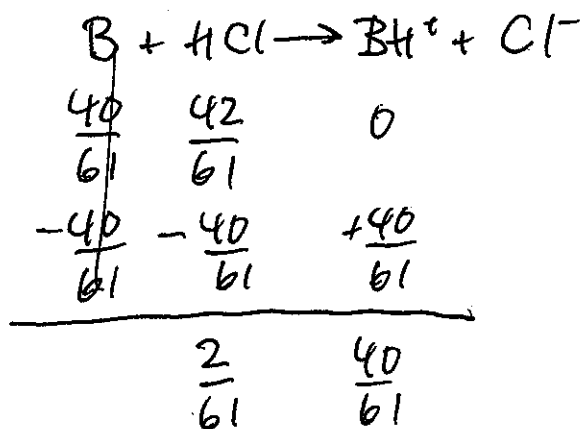


[base] = [salt] so $[H^+]_e = K_a = \frac{1 \times 10^{-14}}{1 \times 10^{-4}} = 1 \times 10^{-10}$

and pH = 10.0

b) [2 marks] 20.0 mL of 1.0 M B and 10.5 mL of 2.0 M HCl

$$[B] = \frac{20}{30.5} \times 1 = \frac{40}{61} \text{ M} \quad [HCl] = \frac{10.5}{30.5} \times 2 = \frac{42}{61} \text{ M}$$



Since strong acid is in excess, $[H^+]_e = \frac{2}{61} \text{ M}$, and pH is 1.48

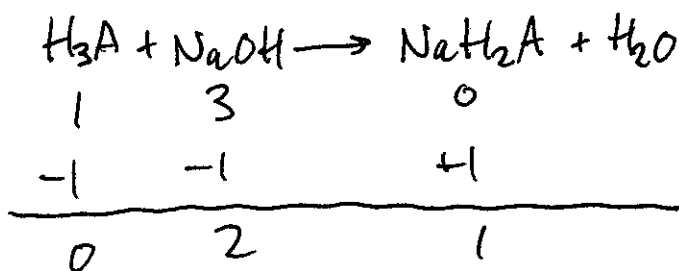
12) [6 marks total] H_3A is a weak polyprotic acid with $pK_{a1} = 3.0$, $pK_{a2} = 7.0$, and $pK_{a3} = 11.0$. Calculate the pH (at $25^\circ C$) of the following solutions made using H_3A and/or its salts:

a) [2 marks] 20.0 mL of 4.0 M NaH_2A

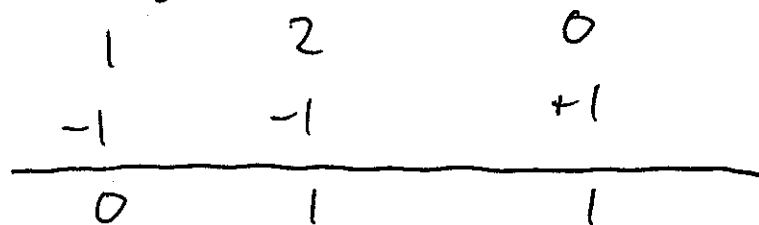
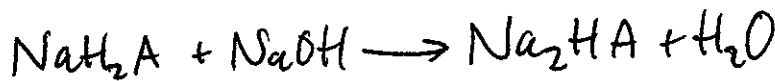
$$pH = \frac{1}{2}(pK_{a1} + pK_{a2}) = \boxed{5.0}$$

b) [4 marks] 20.0 mL of 4.0 M H_3A and 60.0 mL of 4.0 M $NaOH$

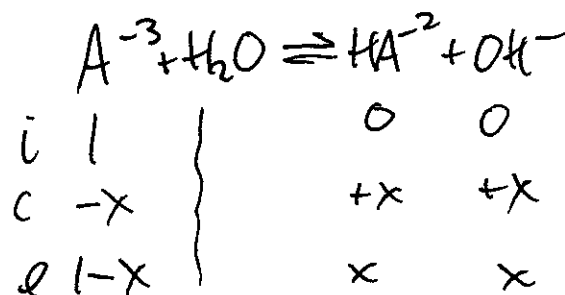
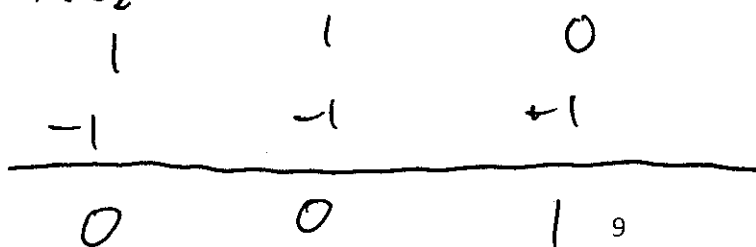
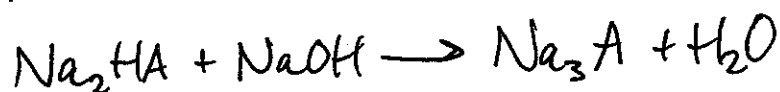
$$[H_3A] = \frac{20}{80} \times 4 = 1M \quad [NaOH] = \frac{60}{80} \times 4 = 3M$$



rxn continues...



rxn continues...



$$\frac{x^2}{1-x} = \frac{1 \times 10^{-14}}{1 \times 10^{-11}} = 1 \times 10^{-3}$$

$$x = [OH^{-}]_e = 3.2 \times 10^{-2} M$$

$$pOH = 1.5$$

$$\text{so } pH = \boxed{12.5}$$