

Part I: Mult. Choice - No Partial Credit

1.(5 pts) From which of the following compounds would it be most difficult to obtain pure water by reverse osmosis?

$$\pi = i M R T$$

- | | | |
|-----------|--|------------------|
| A. | 1.0 M FeCl ₃ | $4 \times 1 = 4$ |
| B. | 3.0 M ethanol (C ₂ H ₅ OH) | $3 \times 1 = 3$ |
| <u>C.</u> | 2.0 M Ba(OH) ₂ | $3 \times 2 = 6$ |
| D. | 1.0 M Cu(ClO ₄) ₂ | $3 \times 1 = 3$ |
| E. | 2.0 M NaCl | $2 \times 2 = 4$ |

2.(5 pts) Colligative properties are those that

A. ~~are those that~~ do not depend on the temperature and pressure but do depend on the type of solute which is dissolved in the solvent.

B. change the concentration of a solute in a solution.

C. result from a change in vapor pressure of the solute when it is dissolved in the solvent.

D. are only observed for pure solvents.

E. depend on the number of solute particles in a solution and not on the type of particle.

3.(5 pts) Which of the following weak acids has the strongest conjugate base?

A. HC₂H₃O₂ ($K_a = 1.7 \times 10^{-5}$)

B. HCN ($K_a = 4.8 \times 10^{-10}$)

C. HF ($K_a = 6.8 \times 10^{-4}$)

D. HCHO₂ ($K_a = 1.8 \times 10^{-4}$)

E. HClO ($K_a = 3.0 \times 10^{-8}$)

4.(5 pts) For a solution labelled "0.20 M barium hydroxide", which of the following is correct?

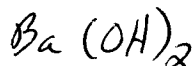
A. [OH⁻] = 0.20 M, [Ba²⁺] = 0.20 M

B. [OH⁻] = 0.40 M, [Ba²⁺] = 0.20 M

C. [OH⁻] = 0.20 M, [Ba²⁺] = 0.10 M

D. [OH⁻] = 0.20 M, [Ba²⁺] = 0.40 M

E. [OH⁻] = 0.40 M, [Ba²⁺] = 0.40 M



5.(5 pts) When equal volumes of 0.10 M aqueous solutions of HF and KOH are mixed, the pH of the resulting solution will be

A. between 1 and 7

B. between 7 and 13

C. equal to the value of the pK_a for HF

D. equal to 7

E. equal to the pK_b for F⁻

weak strong
acid base

6.(10 pts) Blood, sweat and tears are about 0.15 M in NaCl. Estimate the osmotic pressure of these solutions at 37°C:

- ☒ A. 7.6 atm
- ☐ B. 3.8 atm
- ☐ C. 0.91 atm
- ☐ D. 1.8 atm
- ☐ E. 11 atm

$$\pi = i M R T$$

$$i = 2$$

$$M = 0.15$$

$$R = \cancel{0.08206 \text{ L} \cdot \text{atm} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}} 8.20578 \text{ L} \cdot \text{atm} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$$

$$T = 37 + 273.15 = 310.15 \text{ K}$$

7.(10 pts) Consider the following reaction



The value of K_c for the reaction is 2.80 at 873 K. At equilibrium, the concentrations of N_2O and O_2 are 0.80 M and 0.60 M, respectively. Calculate the concentration of N_2 .

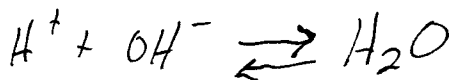
- ☐ A. 3.7 M
- ☐ B. 0.62 M
- ☐ C. 3.0 M
- ☒ D. 1.7 M
- ☐ E. 4.7 M

$$K_c = \frac{[\text{N}_2]^2 [\text{O}_2]}{[\text{N}_2\text{O}]^2}$$

$$[\text{N}_2] = \left(\frac{2.80 \times (0.8)^2}{0.6} \right)^{1/2}$$

8.(5 pts) The equilibrium constant for the reaction of $\text{KOH}(\text{aq})$ with $\text{HCl}(\text{aq})$ is

- ☐ A. unknown
- ☐ B. 1.0×10^{-14}
- ☐ C. 1.0×10^{28}
- ☒ D. 1.0×10^{14}
- ☐ E. 1.0×10^7



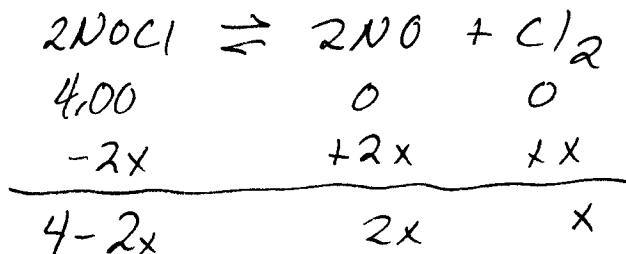
$$K = K_w^{-1} = 10^{14}$$

9.(20 pts) Consider the following reaction:



If, initially $[\text{NOCl}] = 4.00 \text{ M}$, all others are zero, and at equilibrium, $[\text{NO}] = 1.32 \text{ M}$, calculate the value of K_c .

- A. 0.33
☒ B. 0.16
 C. 2.85
 D. 0.072
 E. 0.020

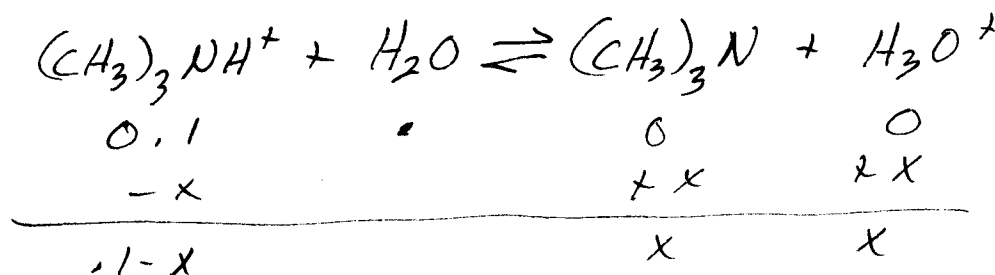


$$2x = 1.32 \quad x = 0.66$$

$$K_c = \frac{(1.32)^2 \cdot 0.66}{(4-1.32)^2}$$

10.(20 pts) The pH of a 0.10 M $(\text{CH}_3)_3\text{NHCl}$ aqueous solution is 5.40. The value of K_b for $(\text{CH}_3)_3\text{N}$ is

- A. 4.0×10^{-6}
 B. 1.6×10^{-11}
☒ C. 6.3×10^{-5}
 D. 1.6×10^{-10}
 E. 2.5×10^{-10}



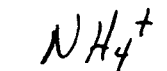
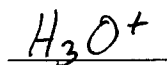
$$x = 10^{-5.40} = 3.98 \times 10^{-6} \text{ M}$$

$$K_b = \frac{K_w}{K_a} = 6.3 \times 10^{-5} \quad K_a = \frac{(3.98 \times 10^{-6})^2}{0.1 - 3.98 \times 10^{-6}} = 1.58 \times 10^{-10}$$

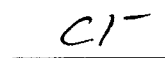
Part II: Show all work for partial credit!

11.(20 pts) Fill in the following table: (No credit for incorrect formulae or charges.)

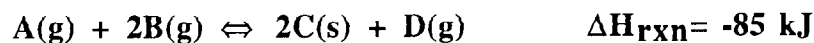
conjugate acid



conjugate base



12.(20 pts total) Consider the following reaction allowed to come to equilibrium:



If equilibrium is perturbed by the following changes, what will be the effect on the indicated quantity when equilibrium is reestablished?

Change in conditions:	Effect on Rxn:		
	Increase	Decrease	No Change
(a) If more D(g) is added, what is the effect on the amount of B(g) present?	<u>X</u>	_____	_____
(b) If more C(s) is added, what is the effect on the amount of B(g) present?	_____	_____	<u>X</u>
(c) If the temperature is increased, what is the effect on the value of K?	_____	<u>X</u>	_____
(d) If the volume of the reaction vessel is increased, what is the effect on the amount of D(g) present?	_____	<u>X</u>	_____
(e) If more B(g) is added, what is the effect on the value of K?	_____	_____	<u>X</u>

13.(15 pts) Calculate the molar mass of an unknown aqueous acid (HA) if it takes 30 mL of 0.150 M KOH(aq) to reach the equivalence point when 0.374 g of the acid is dissolved in 25.0 mL of solution.

$$\text{moles acid} = \text{moles base}$$

$$\text{NaOH: } .030 \text{ L} \times 0.15 \text{ M} = 4.5 \times 10^{-3} \text{ moles}$$

$$\frac{0.374 \text{ g}}{4.5 \times 10^{-3} \text{ moles}} = 83.11$$

14. (25 pts total) A solution (~194 mL) contains 1 mole of benzene (~88 mL) and 2 moles of toluene (~106 mL). Given that the equilibrium vapor pressure at 81°C of pure benzene is 768 torr while that of toluene is 293 torr, calculate:

(a) (15 pts) the total vapor pressure (in torr) above the solution at 81°C

$$P_{\text{Benz}} = X_{\text{Ben, soln}} P_{\text{Benz}}^{\circ} = \frac{1 \text{ mol}}{1 + 2 \text{ mol}} * 768 = 256$$

$$P_{\text{Toluene}} = X_{\text{Tol, soln}} P_{\text{Tol}}^{\circ} = \frac{2}{1 + 2} * 293 = 195$$

$$P_{\text{total}} = P_{\text{Benz}} + P_{\text{Tol}} = 195 + 256 = 451 \text{ Torr}$$

(b) (10 pts) the mole fraction of toluene in the vapor above the 81°C solution

$$X_{\text{gas, tol}} = \frac{n_{\text{Tol, gas}}}{n_{\text{Tol, gas}} + n_{\text{Benz, gas}}} = \frac{P_{\text{Tol}}}{P_{\text{Tol}} + P_{\text{Benz}}} = 0.43$$

15. (40 Pts) The osmotic pressure of 300 mg of a large biomolecule (a non-electrolyte) dissolved in enough water to give 25.0 mL of solution is 7.10 Torr at 25°C. Calculate the molar mass of the biomolecule.

$\rightarrow i = 1$

$$\pi = i M R T, \quad \text{MW} = \frac{g}{\text{mol}}; \quad \text{moles} = \text{vol} \times \frac{\text{mol}}{\text{L}}$$

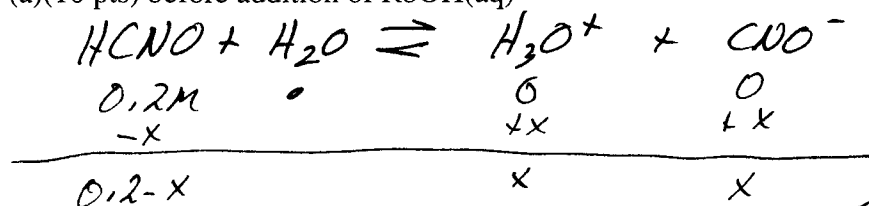
$$i = 1; \quad R = 62.3639 \text{ L} \cdot \text{Torr} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}, \quad T = 25 + 273.15 = 298.15$$

$$M = \frac{\pi}{RT}; \quad \text{moles} = 0.025 \text{ L} * \frac{\pi}{RT}$$

$$\text{MW} = \frac{0.300 \text{ g}}{0.025 \text{ L} * \frac{7.10 \text{ Torr}}{62.3639 \frac{\text{L} \cdot \text{Torr}}{\text{K} \cdot \text{mol}} * 298.15 \text{ K}}} = 31,426 \frac{\text{g}}{\text{mol}}$$

16. (40 pts total) Calculate the pH for the following cases in the titration of 25.0 mL of 0.2M cyanic acid (HCNO, $pK_a = 3.66$) with 0.2M RbOH solution:

(a) (10 pts) before addition of RbOH(aq)



$$K_a = 10^{-3.66} = 2.19 \times 10^{-4}$$

$$2.19 \times 10^{-4} = \frac{x^2}{0.2-x}$$

assume $x \ll 0.2$

$$x = (0.2 \times 2.19 \times 10^{-4})^{1/2}$$

$$x = 6.6 \times 10^{-3}$$

($\frac{x}{0.2} = 0.033 \therefore$ assumption OK)

$$-\log(x) = \text{pH} = 2.18$$

(b) (10 pts) after addition of 12.50 mL RbOH(aq)

$$\text{React: moles OH}^- = 12.50 \text{ mL} \times 0.2 \text{ M} = 2.5 \text{ mmol}$$

$$\text{moles HCNO} = 25.0 \text{ mL} \times 0.2 \text{ M} = 5.0 \text{ mmol}$$

$$\text{moles base} = \frac{1}{2} \text{ moles acid} = \frac{1}{2} \text{-way pt}$$

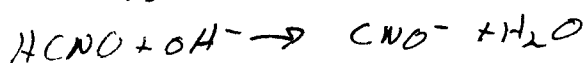
$$\text{pH} = \text{p}K_a = 3.66$$

(c) (15 pts) after addition of 25.00 mL RbOH(aq)

$$\text{React: moles OH}^- = 25 \text{ mL} \times 0.2 \text{ M} = 5.0 \text{ mmol}$$

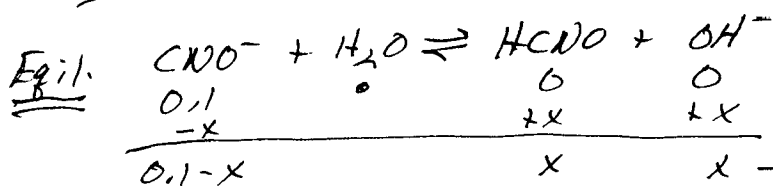
$$\text{moles HCNO} = 5.0 \text{ mmol}$$

\therefore stoichiometric pt.



$$\text{Final } 5-5 \quad 5-5 \quad 0+5 \quad \cdot$$

$$\text{Dilute } \frac{5.0 \text{ mmol CNO}^-}{25+25 \text{ mL}} = 0.1 \text{ M}$$



$$K_b = \frac{K_w}{K_a} = \frac{1 \times 10^{-14}}{2.19 \times 10^{-4}} = 4.57 \times 10^{-11}$$

$$4.57 \times 10^{-11} = \frac{x^2}{0.1-x}$$

Assume $x \ll 0.1$

$$x = (0.1 \times 4.57 \times 10^{-11})^{1/2} =$$

$$2.14 \times 10^{-6} = [\text{OH}^-]$$

(assump. OK)

$$\text{pH} = 14 + \log(2.14 \times 10^{-6})$$

$$\text{pH} = 8.33$$

(d) (5 pts) after addition of 30.00 mL of RbOH(aq)

$$\text{Rxt moles OH}^- = 30 \text{ mL} \times 0.2 \text{ M} = 6 \text{ mmol}$$

$$\text{moles HCNO} = 5 \text{ mmol}$$

\therefore 1 mmol excess OH^- in

$$(30+25) \text{ mL} \Rightarrow 1.82 \times 10^{-2} = [\text{OH}^-]$$

$$\text{pH} = 14 + \log(1.82 \times 10^{-2}) = 12.26$$