Exam II: Spr. '99 Key

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_2H_5OH) — $3 \times 1 = 3$
C. 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. $HC_2H_3O_2$ ($K_a = 1.7 \times 10^{-5}$)
B. HCN ($K_a = 4.8 \times 10^{-10}$)
C. HF ($K_a = 6.8 \times 10^{-4}$)
D. $HCHO_2$ ($K_a = 1.8 \times 10^{-4}$)
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?

$Ba(OH)_2$

A. $[OH^-] = 0.20$ M, $[Ba^{2+}] = 0.20$ M
B. $[OH^-] = 0.40$ M, $[Ba^{2+}] = 0.20$ M
C. $[OH^-] = 0.20$ M, $[Ba^{2+}] = 0.10$ M
D. $[OH^-] = 0.20$ M, $[Ba^{2+}] = 0.40$ M
E. $[OH^-] = 0.40$ M, $[Ba^{2+}] = 0.40$ 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

weak acid — strong base

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^-

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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

$\pi = i\,MRT$

$i = 2$

$M = 0.15$

$R = \cancel{62.3637\ L \cdot atm}$
$8.20578\ L \cdot atm \cdot K^{-1} Mol^{-1}$

$T = 37 + 273.15 = 310.15\ K$

7.(10 pts) Consider the following reaction

$$2N_2O(g) \Leftrightarrow 2N_2(g) + O_2(g)$$

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. 3.0M
D. 1.7 M
E. 4.7 M

$$K_c = \frac{[N_2]^2[O_2]}{[N_2O]^2}$$

$$[N_2] = \left(\frac{2.80 \times (0.8)^2}{0.6}\right)^{1/2}$$

8.(5 pts) The equilibrium constant for the reaction of KOH(aq) with HCl(aq) is

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

$H^+ + OH^- \rightleftarrows H_2O$

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

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9.(20 pts) Consider the following reaction:

2NOCl(g) ⇔ 2NO(g) + Cl2(g)

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

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

$$
\begin{array}{ccc}
2NOCl & \rightleftharpoons 2NO & + Cl_2 \\
4.00 & 0 & 0 \\
-2x & +2x & +x \\
\hline
4-2x & 2x & x
\end{array}
$$

$2x = 1.32 \quad x = 0.66$

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

10.(20 pts) The pH of a 0.10 M $(CH_3)_3NHCl$ aqueous solution is 5.40. The value of K_b for $(CH_3)_3N$ 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}

$$
\begin{array}{cccc}
(CH_3)_3NH^+ & + H_2O \rightleftharpoons & (CH_3)_3N & + H_3O^+ \\
0.1 & & 0 & 0 \\
-x & & +x & +x \\
\hline
.1-x & & x & x
\end{array}
$$

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

$K_a = \frac{(3.98 \times 10^{-6})^2}{0.1 - 3.98 \times 10^{-6}} = 1.58 \times 10^{-10}$

$K_b = \frac{K_w}{K_a} = 6.3 \times 10^{-5}$

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
H_3O^+	H_2O
H_2O	OH^-
NH_4^+	NH_3
HCl	Cl^-
H_2CO_3	HCO_3^-

Key Exam II

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

$$A(g) + 2B(g) \Leftrightarrow 2C(s) + D(g) \qquad \Delta H_{rxn} = -85 \text{ kJ}$$

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?	X		
(b) If more C(s) is added, what is the effect on the amount of B(g) present?			X
(c) If the temperature is increased, what is the effect on the value of K?		X	
(d) If the volume of the reaction vessel is increased, what is the effect on the amount of D(g) present?		X	
(e) If more B(g) is added, what is the effect on the value of K?			X

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.

moles acid = moles base

NaOH: .030 L * 0.15 M = 4.5*10^-3 moles

$$\frac{.374 \text{ g}}{4.5 \times 10^{-3} \text{ moles}} = 83.11$$

Key Exam II

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

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

$$P_{Toluene} = X_{Tol, soln} P^{o}_{Tol} = \frac{2}{1+2} * 293 = 195$$

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

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

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

$$= 0.43$$

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.

$\rightarrow i = 1$

$$\pi = i M R T, \quad mw = \frac{g}{mol}; \quad moles = vol * \frac{mol}{L}$$

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

$$M = \frac{\pi}{RT}; \quad moles = .025L * \frac{\pi}{RT}$$

$$mW = \frac{0.300 g}{.025L * \dfrac{7.10 \text{ Torr}}{62.3639 \frac{L \cdot Torr}{K \cdot mol} * 298.15 K}} = 31,426 \frac{g}{mol}$$

Key Exam II

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)

$$HCNO + H_2O \rightleftharpoons H_3O^+ + CNO^-$$

0.2M	•	0	0
−x		+x	+x
0.2−x		x	x

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

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

assume x<<0.2

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

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

($\frac{x}{.2} = .03 \therefore$ assmp. OK)

$-\log(x) = pH = 2.18$

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

React: moles OH^- = 12.50 ml * 0.2M = 2.5 mmoles

moles HCNO = 25.0 ml * 0.2M = 5.0 mmoles

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

$pH = pK_a = 3.66$

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

React: moles OH^- = 25 ml * 0.2M = 5.0 mmoles

moles HCNO = 5.0 mmoles

∴ Stoichiometric pt.

$$HCNO + OH^- \rightarrow CNO^- + H_2O$$

Final 5−5 5−5 0+5 •

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

Equil. $$CNO^- + H_2O \rightleftharpoons HCNO + OH^-$$

0.1	•	0	0
−x		+x	+x
0.1−x		x	x

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

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

Assume x<<0.1

$x = (0.1 * 4.57 \times 10^{-11})^{1/2} = 2.14 \times 10^{-6} = [OH^-]$

(assump. OK)

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

$pH = 8.33$

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

Rxt moles OH^- = 30 ml × 0.2M = 6 mmol

moles HCNO = 5 mmol

∴ 1 mmol excess OH^- } in (30+25) ml ⟹ $1.82 \times 10^{-2} = [OH^-]$

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