1

ANSWER KEY

CHEMISTRY S14O4 FIRST EXAM 7/15/99
PROFESSOR J. MORROW

PRINT NAME, LAST: ____________________________

FIRST: ____________________________

I.D.# : ____________________________

EACH QUESTION IS WORTH 1O POINTS

1. ________	7. ________	12. ________
2. ________	8. ________	13. ________
3. ________	9. ________	14. ________
4. ________	10. ________	15. ________
5. ________	11. ________	16. ________
6. ________		

COLUMN TOTALS: (MAXIMUM)

________(60) ________(50) ________(50)

EXAM TOTAL (14O pts) ___________ ___________
OUT OF 1OO

THIS INFORMATION IS FOR PROBLEMS 1 AND 2.

You are given a triprotic acid, H_3X, with $K_{a1} = 1.OOx1O^{-7}$, $K_{a2} = 1.OOx1O^{-12}$ and $K_{a3} = 1.OOx1O^{-16}$. $K_{a1} = \frac{[H^+][H_2X^-]}{[H_3X]}$, $K_{a2} = \frac{[H^+][HX^{2-}]}{[H_2X^-]}$, $K_{a3} = \frac{[H^+][X^{3-}]}{[HX^{2-}]}$

1) Calculate the ratio $\frac{[HX^{2-}]}{[H_2X^-]}$ present in a solution whose pH = 4.OO if <u>H_3X is the only solute.</u>

i) $1.Ox1O^{-3}$ ii) $1.Ox1O^{-12}$ iii) $1.Ox1O^{-8}$ iv) $1.Ox1O^{-1O}$

1. $H_3X \rightleftharpoons H^+ + H_2X^-$ $[H^+] = [H_2X^-] = 1O^{-4}$ M

2. $H_2X^- \rightleftharpoons H^+ + HX^{2-}$

$$K_{a2} = 1.OOx1O^{-12} = \frac{[H^+][HX^{2-}]}{[H_2X^-]} \quad \backslash \quad \frac{[H_2X^-]}{[HX^{2-}]} = \frac{1.OOx1O^{-12}}{[H^+]}$$

$$\backslash \quad \frac{[H_2X^-]}{[HX^{2-}]} = \frac{1.OOx1O^{-12}}{[H^+]} = \frac{1.OOx1O^{-12}}{1O^{-4}} = 1.Ox1O^{-8}$$

ANSWER IS: <u>$1.Ox1O^{-8}$</u>

2) Calculate the $[H_3X]$ in the above solution from problem 1.

i) 0.30 ii) 0.25 iii) 0.15 iv) 0.10 v) 0.050

$$H_3X \rightleftharpoons H^+ + H_2X^- \quad [H^+] = [H_2X^-] = 1O^{-4}\ M$$

c - x x x where x = $1O^{-4}$ M

$$K_{a1} = 1.OOx1O^{-7} = \frac{[H^+][H_2X^-]}{[H_3X]} = \frac{(1O^{-4})^2}{c-1O^{-4}} = \frac{(1O^{-4})^2}{c}$$

\ c = O.1O M

ANSWER IS: <u>O.1O M</u>

THE FOLLOWING INFORMATION IS FOR PROBLEMS 3 AND 4.

Given a sparingly soluble salt, M_3X_2 , where X is the anion from the weak triprotic acid given in problem 1. ($K_{a1} = 1.OOx1O^{-7}$, $K_{a2} = 1.OOx1O^{-12}$, and and $K_{a3} = 1.OOx1O^{-16}$) .

For this sparingly soluble salt, M_3X_2 , $K_{sp} = 1.OOx1O^{-44}$.

EACH QUESTION IS INDEPENDENT OF THE OTHER. SHOW WORK

3) What is the solubility of M_3X_2 in pure water. Neglect the hydrolysis of X^{3-} .

i) $1.58x1O^{-10}$ ii) $6.21x1O^{-10}$ iii) $18.6x1O^{-1O}$ iv) $12.4x1O^{-10}$

$$M_3X_2 \rightleftharpoons 3\,M^{2+} + 2\,X^{3-}$$

$$K_{sp} = 1.OOx1O^{-44} = [M^{2+}]^3[X^{3-}]^2 = [3x]^3[2x]^2 = 1O8x^5$$

$\therefore$ solubility = x = $O.621x1O^{-9}$ M = $6.21x1O^{-10}$ M

ANSWER IS: $6.21x1O^{-10}$

4) What is the solubility of M_3X_2 in a solution containing O.O1O M Na_3X ? Neglect the hydrolysis of X^{3-} .

i) $1.55x10^{-14}$ ii) $4.64x10^{-14}$ iii) $2.31x10^{-14}$ iv) $0.77x10^{-14}$

$K_{sp} = 1.OOx1O^{-44} = [M^{2+}]^3[O.O1O]^2$ $\therefore$ $[M^{2+}] = 4.64x1O^{-14}$

Solubility = 1/3 of $[M^{2+}] = 1.55x1O^{-14}$

If answer given is ii, give 7 pts. ANSWER IS: i

5) Consider the weak acids, A, B, C, and D;

ACID	A	B	C	D
pK_a	8.3	2.7	12.9	5.6

List these bases in order of increasing acidity (decreasing basicity);

LEAST ACIDIC C < A < D < B MOST ACIDIC

6) A O.1OO M solution of a salt, KX (which hydrolyzes), has a pH = 9.OO . Calculate the value of K_a for the weak acid, HX. The hydrolysis reaction is, $X^- + H_2O \rightleftharpoons HX + OH^-$

i) $1O^{-4}$ ii) $1O^{-5}$ iii) $1O^{-6}$ iv) $1O^{-7}$ v) $1O^{-8}$

$$X^- + H_2O \rightleftharpoons HX + OH^- \quad \text{where} \quad K_h = \frac{K_w}{K_a} = \frac{[HX][OH^-]}{[X^-]}$$

$$K_h = \frac{K_w}{K_a} = \frac{[HX][OH^-]}{[X^-]} = \frac{(1O^{-5})^2}{O.1} = 1O^{-9} \text{ and } \therefore \; K_a = 1O^{-5}$$

ANSWER IS: $K_a = 1O^{-5}$

THE FOLLOWING INFORMATION IS FOR PROBLEMS 7, 8, AND 9. (SHOW WORK)

25.OO mL of O.1OO M methylamine, CH_3NH_2 , is titrated with O.1OO M HCl. Calculate the pH; (K_b = 4.4 x1O^{-5})

7) before any HCl is added. ($CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$)

$$K_b = \frac{x^2}{O.1O} = 4.4\ x1O^{-5} \quad x = [OH^-] = 2.1\ x1O^{-3} \quad \backslash \quad pOH = 2.68$$

pH = 11.32

8) halfway to the equivalence point.

$$pOH = pK_b = -\log(4.4\ x1O^{-5}) = 4.36 \quad \backslash \quad pH = 9.64$$

pH = 9.64

9) at the equivalence point. (HINT: First solve for K_h) SHOW WORK

i) 2.68 ii) 6.36 iii) 5.47 iv) 10.95 v) 8.24

$$CH_3NH_3^+ + H_2O \rightleftharpoons CH_3NH_2 + H_3O^+$$

At equivalence point total volume is 5O.O mL and $[CH_3NH_3^+]$ = O.O5O M

$$K_h = \frac{1O^{-14}}{4.4x1O^{-5}} = 2.27x1O^{-1O} = \frac{[CH_3NH_2][H_3O^+]}{[CH_3NH_3^+]} = \frac{x^2}{O.O5O}$$

$$x = [H_3O^+] = O.337x1O^{-5} = 3.37x1O^{-6}$$

pH = 5.47

1O) How many milliliters of a O.1OO M HX (a weak acid) solution should be added to 500 mL of O.1OO M NaX solution, to produce a buffer of pH = 5.OO ? For HX , K_a = 4.OOx1O^{-5} (SHOW WORK)

i) 125 ii) 250 iii) 500 iv) 750 v) 1000

$$K_a = 4.OOx1O^{-5} = \frac{[H^+][X^-]}{[HX]} = \frac{(1O^{-5})[X^-]}{[HX]} \quad \backslash \quad \frac{[X^-]}{[HX]} = 4.OO$$

$$\frac{[X^-]}{[HX]} = 4.OO = \frac{O.O50}{x} \quad \backslash \quad x = O.O125 \text{ mol (of HX must be formed)}$$

\ O.O125 mol of HX needed. V_{HX} = O.125 L = 125 mL

ANSWER IS: 125 mL

11) Complete the following table. (for $M(OH)_3$, $K_{sp} = 6.0x10^{-20}$)

$[M^{3+}]$	$[OH^-]$
$6.0x10^{-8}$ M	$1.0x10^{-4}$ M
$6.0x10^{-3}$ M	*$2.15x10^{-6}$* M

12) Given the following K_{sp} values: for $M(OH)_3$, $K_{sp(M)} = 4.00 \times 10^{-14}$;
for $N(OH)_3$, $K_{sp(N)} = 1.00 \times 10^{-13}$.
One mole of each of the above solids is placed in a beaker containing 1 (one) liter of pure water. These solids go into equilibrium with their ions. Calculate the pH of this solution. Do this calculation as accurately as possible. Use of the approximate method is worth 7 points. (SHOW WORK)

i) 10.91   ii) 10.87 (7 points)   iii) 10.29   iv) 10.80

$$M(OH)_3 \rightleftharpoons M^{3+} + 3\ OH^-$$
$$N(OH)_3 \rightleftharpoons N^{3+} + 3\ OH^-$$

EXACT METHOD

$$[OH^-] = 3\{[M^{3+}] + [N^{3+}]\} = 3\left\{ \frac{K_{sp(M)}}{[OH^-]^3} + \frac{K_{sp(N)}}{[OH^-]^3} \right\}$$

$$[OH^-]^4 = 3\{4.00 \times 10^{-14} + 1.00 \times 10^{-13}\} = 4.2x10^{-13}$$

$[OH^-] = 0.805x10^{-3}$ pOH = 3.09 AND pH = 10.91

APPROXIMATE METHOD

$1x10^{-13} = [x][3x]^3$

$1x10^{-13} = 27x^4$

$x = 2.47x10^{-4}$

$[OH^-] = 3x = 7.4x10^{-4}$

pOH=3.13 ; pH= 10.87

GIVE 4 pts IF ANSWER GIVEN IS iii

GIVE 7 pts IF ANSWER GIVEN IS ii ANSWER IS: i

13) Given the following reactions and their equilibrium constants:

1.	$HS^- \rightleftharpoons H^+ + S^{2-}$		K_1
2.	$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$		K_2
3.	$PbS \rightleftharpoons Pb^{2+} + S^{2-}$		K_{sp3}
4.	$PbCO_3 \rightleftharpoons Pb^{2+} + CO_3^{2-}$		K_{sp4}
5.	$H_2O \rightleftharpoons H^+ + OH^-$		K_w

Calculate the value of K (in terms of any or all of the above K values) for the following reaction;

$$PbCO_3 + HS^- \rightleftharpoons PbS + HCO_3^- \qquad K = ?$$

i) $\frac{K_{sp4}K_2}{K_{sp3}K_1}$ ii) $\frac{K_{sp3}K_2}{K_{sp4}K_1}$ iii) $\frac{K_{sp3}K_1}{K_{sp4}K_2}$ iv) $\frac{K_{sp4}K_1}{K_{sp3}K_2}$ v) $\frac{K_{sp4}K_2K_w}{K_{sp3}K_1}$

ANSWER IS: iv

14) A certain metal has a work function, Φ, of 1.5O eV (= 2.4O3x1O^{-19} J). When monochromatic light of wavelength, λ, falls on this metal, photoelectrons are expelled. The kinetic energy of these photoelectrons is 2.64 eV ? What is the wavelength, λ (in nm), of this light ? SHOW WORK

i) 255 ii) 3OO iii) 334 iv) 319

$$\varepsilon = h\nu - \Phi$$

$$\therefore \quad (2.64)(1.6O22x1O^{-19}) = \frac{(6.626x1O^{-34})(3x1O^{8})}{\lambda} - 2.4O3x1O^{-19}$$

$$\lambda = 3.OOx1O^{-7} \text{ m} = 3OO \text{ nm}$$

ANSWER IS: ii

15) An atom has a velocity of 5O.O $\frac{m}{sec}$ and a deBroglie wavelength of 1.991 Å. Which of the following is the element? (Hint:The atomic weights in the Periodic Table are averages over the weights of isotopes. To answer this question, just round off the numbers in the Periodic Table to the nearest integer.) BE CAREFUL WITH UNITS! (SHOW WORK)

i) H   ii) C   iii) Mg   iv) Ti   v) Ca

$$\lambda = \frac{h}{p} = \frac{h}{mv} \quad \backslash \quad m = \frac{h}{v\lambda} = \frac{6.626x1O^{-34}}{(5O.O)(1.991x1O^{-1O})}$$

$$m = 6.656x1O^{-26}\,\frac{kg}{atom} = 6.656x1O^{-23}\,\frac{g}{atom} = 4O.1\,\frac{g}{mol}$$

ANSWER IS: **V**

16) The linear velocity, v, of an electron in the hydrogen atom (according to the Bohr Theory) is,

$$v = \frac{2\text{ð}e^2}{nh}$$

where: n = principle quantum number, h = Plancks constant
m_e = electron mass, e = q = electron charge, ð = 3.14

What is the de Broglie wavelength, λ (in Å), of an electron in the first shell of the H atom? (HINT: Use the cgs system) SHOW WORK

i) O.O332   ii) 384   iii) 3.32   iv) 6.64   v) 332

$$v = \frac{2\text{ð}e^2}{nh} = \frac{(2)(3.14)(4.8O6x1O^{-1O})^2}{(1)(6.626x1O^{-27})} \quad \text{(in cgs units)}$$

$$v = 21.89x1O^{7}\,\frac{cm}{sec}\ \text{(c.g.s. units)} = 21.89x1O^{5}\,\frac{m}{sec}\ \text{(S.I. units)}$$

$$\lambda = \frac{h}{mv} = \frac{6.626x1O^{-34}}{(9.1O8x1O^{-31})(21.89x1O^{5})} = 3.32x1O^{-1O}\ m = 3.32\ \text{Å}$$

ANSWER IS: iii