

ANSWER KEY

CHEMISTRY S1404
PROFESSOR J. MORROW

FIRST EXAM

7/15/99

PRINT NAME, LAST: _____

FIRST: _____

I.D.# : _____

EACH QUESTION IS WORTH 10 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 (140 pts) _____

OUT OF 100

THIS INFORMATION IS FOR PROBLEMS 1 AND 2.

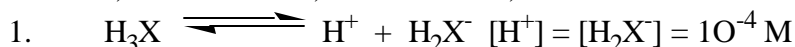
You are given a triprotic acid, H_3X , with $K_{a1} = 1.00 \times 10^{-7}$, $K_{a2} = 1.00 \times 10^{-12}$

and $K_{a3} = 1.00 \times 10^{-16}$. $K_{a1} = \frac{[H^+][H_2X^-]}{[H_3X]}$, $K_{a2} = \frac{[H^+][HX^{2-}]}{[H_2X^-]}$, $K_{a3} = \frac{[H^+][X^{3-}]}{[HX^{2-}]}$

1) Calculate the ratio $\frac{[HX^{2-}]}{[H_2X^-]}$ present in a solution whose pH = 4.00 if

H_3X is the only solute.

i) 1.0×10^{-3} ii) 1.0×10^{-12} iii) 1.0×10^{-8} iv) 1.0×10^{-10}



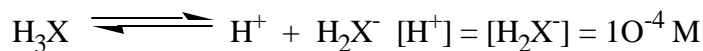
$$K_{a2} = 1.00 \times 10^{-12} = \frac{[H^+][HX^{2-}]}{[H_2X^-]} \quad \backslash \quad \frac{[H_2X^-]}{[HX^{2-}]} = \frac{1.00 \times 10^{-12}}{[H^+]}$$

$$\backslash \quad \frac{[H_2X^-]}{[HX^{2-}]} = \frac{1.00 \times 10^{-12}}{[H^+]} = \frac{1.00 \times 10^{-12}}{10^{-4}} = 1.0 \times 10^{-8}$$

ANSWER IS: 1.0×10^{-8}

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



c-x x x where $x = 10^{-4} \text{ M}$

$$K_{a1} = 1.00 \times 10^{-7} = \frac{[H^+][H_2X^-]}{[H_3X]} = \frac{(10^{-4})^2}{c - 10^{-4}} = \frac{(10^{-4})^2}{c}$$

$$\backslash \quad c = 0.10 \text{ M}$$

ANSWER IS: 0.10 M

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. ($K_{a1} = 1.00 \times 10^{-7}$, $K_{a2} = 1.00 \times 10^{-12}$, and $K_{a3} = 1.00 \times 10^{-16}$).

For this sparingly soluble salt, M_3X_2 , $K_{sp} = 1.00 \times 10^{-44}$.

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) 1.58×10^{-10} ii) 6.21×10^{-10} iii) 18.6×10^{-10} iv) 12.4×10^{-10}



$$K_{sp} = 1.00 \times 10^{-44} = [M^{2+}]^3 [X^{3-}]^2 = [3x]^3 [2x]^2 = 108x^5$$

$$\backslash \text{ solubility} = x = 0.621 \times 10^{-9} \text{ M} = 6.21 \times 10^{-10} \text{ M}$$

ANSWER IS: 6.21×10^{-10}

4) What is the solubility of M_3X_2 in a solution containing 0.010 M Na_3X ? Neglect the hydrolysis of X^{3-} .

- i) 1.55×10^{-14} ii) 4.64×10^{-14} iii) 2.31×10^{-14} iv) 0.77×10^{-14}

$$K_{sp} = 1.00 \times 10^{-44} = [M^{2+}]^3 [0.010]^2 \quad \backslash \quad [M^{2+}] = 4.64 \times 10^{-14}$$

$$\text{Solubility} = 1/3 \text{ of } [M^{2+}] = 1.55 \times 10^{-14}$$

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

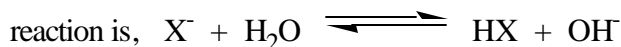
5) Consider the weak acids, A, B, C, and D;

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 0.100 M solution of a salt, KX (which hydrolyzes), has a pH = 9.00. Calculate the value of K_a for the weak acid, HX. The hydrolysis



- i) 10^{-4} ii) 10^{-5} iii) 10^{-6} iv) 10^{-7} v) 10^{-8}

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

$$K_h = \frac{K_w}{K_a} = \frac{[HX][OH^-]}{[X^-]} = \frac{(10^{-5})^2}{0.1} = 10^{-9} \quad \text{and} \quad \backslash \quad K_a = 10^{-5}$$

ANSWER IS: $K_a = 10^{-5}$

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

25.00 mL of 0.100 M methylamine, CH_3NH_2 , is titrated with 0.100 M HCl. Calculate the pH; ($K_b = 4.4 \times 10^{-5}$)

7) before any HCl is added. ($\text{CH}_3\text{NH}_2 + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{NH}_3^+ + \text{OH}^-$)

$$K_b = \frac{x^2}{0.10} = 4.4 \times 10^{-5} \quad x = [\text{OH}^-] = 2.1 \times 10^{-3} \quad \backslash \quad \text{pOH} = 2.68$$

$$\text{pH} = \underline{11.32}$$

8) halfway to the equivalence point.

$$\text{pOH} = \text{p}K_b = -\log(4.4 \times 10^{-5}) = 4.36 \quad \backslash \quad \text{pH} = 9.64$$

$$\text{pH} = \underline{9.64}$$

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



At equivalence point total volume is 50.0 mL and $[\text{CH}_3\text{NH}_3^+] = 0.050 \text{ M}$

$$K_h = \frac{10^{-14}}{4.4 \times 10^{-5}} = 2.27 \times 10^{-10} = \frac{[\text{CH}_3\text{NH}_2][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{NH}_3^+]} = \frac{x^2}{0.050}$$

$$x = [\text{H}_3\text{O}^+] = 0.337 \times 10^{-5} = 3.37 \times 10^{-6}$$

$$\text{pH} = \underline{5.47}$$

10) How many milliliters of a 0.100 M HX (a weak acid) solution should be added to 500 mL of 0.100 M NaX solution, to produce a buffer of $\text{pH} = 5.00$? For HX, $K_a = 4.00 \times 10^{-5}$ (SHOW WORK)

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

$$K_a = 4.00 \times 10^{-5} = \frac{[\text{H}^+][\text{X}^-]}{[\text{HX}]} = \frac{(10^{-5})[\text{X}^-]}{[\text{HX}]} \quad \backslash \quad \frac{[\text{X}^-]}{[\text{HX}]} = 4.00$$

$$\frac{[\text{X}^-]}{[\text{HX}]} = 4.00 = \frac{0.050}{x} \quad \backslash \quad x = 0.0125 \text{ mol (of HX must be formed)}$$

$$\backslash \quad 0.0125 \text{ mol of HX needed. } V_{\text{HX}} = 0.125 \text{ L} = 125 \text{ mL}$$

ANSWER IS: 125 mL

11) Complete the following table. (for $M(OH)_3$, $K_{sp} = 6.0 \times 10^{-20}$)

$[M^{3+}]$	$[OH^-]$
$6.0 \times 10^{-8} \text{ M}$	$1.0 \times 10^{-4} \text{ M}$
$6.0 \times 10^{-3} \text{ M}$	$2.15 \times 10^{-6} \text{ M}$

12) Given the following K_{sp} values: for $M(OH)_3$, $K_{sp(M)} = 4.00 \times 10^{-14}$;

for $N(OH)_3$, $K_{sp(N)} = 1.00 \times 10^{-13}$.

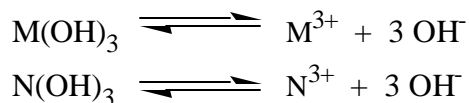
One mole of each of the above solids is placed in a beaker containing 1 (one) liter of pure water. These solids go into equilibrium with their ions. Calculate the pH of this solution. Do this calculation as accurately as possible. Use of the approximate method is worth 7 points. (SHOW WORK)

i) 10.91

ii) 10.87 (7 points)

iii) 10.29

iv) 10.80



EXACT METHOD

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

$$[OH^-]^4 = 3\{4.00 \times 10^{-14} + 1.00 \times 10^{-13}\} = 4.2 \times 10^{-13} \quad x = 2.47 \times 10^{-4}$$

$$[OH^-] = 0.805 \times 10^{-3} \quad pOH = 3.09 \quad \text{AND} \quad pH = 10.91 \quad pOH = 3.13 ; pH = 10.87$$

APPROXIMATE METHOD

$$1 \times 10^{-13} = [x][3x]^3$$

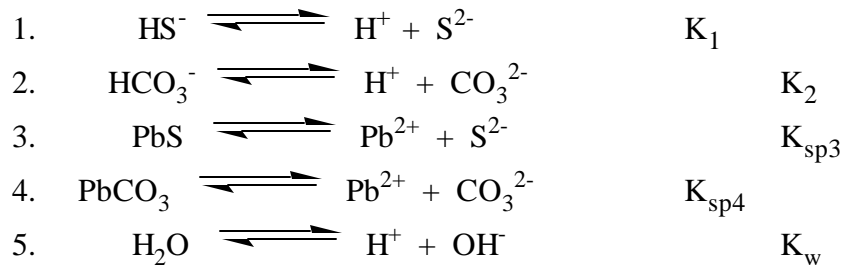
$$1 \times 10^{-13} = 27x^4$$

$$[OH^-] = 3x = 7.4 \times 10^{-4}$$

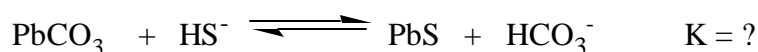
GIVE 4 pts IF ANSWER GIVEN IS iii

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

13) Given the following reactions and their equilibrium constants:



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



$$\text{i) } \frac{K_{\text{sp}4}K_2}{K_{\text{sp}3}K_1} \quad \text{ii) } \frac{K_{\text{sp}3}K_2}{K_{\text{sp}4}K_1} \quad \text{iii) } \frac{K_{\text{sp}3}K_1}{K_{\text{sp}4}K_2} \quad \text{iv) } \frac{K_{\text{sp}4}K_1}{K_{\text{sp}3}K_2} \quad \text{v) } \frac{K_{\text{sp}4}K_2K_w}{K_{\text{sp}3}K_1}$$

ANSWER IS: iv

14) A certain metal has a work function, Φ , of 1.50 eV ($= 2.403 \times 10^{-19}$ 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

$$\text{i) } 255 \quad \text{ii) } 300 \quad \text{iii) } 334 \quad \text{iv) } 319$$

$$\mathcal{E} = h\nu - \Phi$$

$$\lambda \quad (2.64)(1.6022 \times 10^{-19}) = \frac{(6.626 \times 10^{-34})(3 \times 10^8)}{\lambda} - 2.403 \times 10^{-19}$$

$$\lambda = 3.00 \times 10^{-7} \text{ m} = 300 \text{ nm}$$

ANSWER IS: ii

- 15) An atom has a velocity of $50.0 \frac{\text{m}}{\text{sec}}$ and a deBroglie wavelength of 1.991 \AA . 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

$$\lambda = \frac{h}{p} = \frac{h}{mv} \quad \backslash \quad m = \frac{h}{v\lambda} = \frac{6.626 \times 10^{-34}}{(50.0)(1.991 \times 10^{-10})}$$

$$m = 6.656 \times 10^{-26} \frac{\text{kg}}{\text{atom}} = 6.656 \times 10^{-23} \frac{\text{g}}{\text{atom}} = 40.1 \frac{\text{g}}{\text{mol}}$$

ANSWER IS: V

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

$$v = \frac{2\tilde{\theta}e^2}{nh}$$

where: n = principle quantum number, h = Planck's constant
 m_e = electron mass, $e = q$ = electron charge, $\tilde{\theta} = 3.14$

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

i) 0.0332 ii) 384 iii) 3.32 iv) 6.64 v) 332

$$v = \frac{2\tilde{\theta}e^2}{nh} = \frac{(2)(3.14)(4.806 \times 10^{-10})^2}{(1)(6.626 \times 10^{-27})} \quad (\text{in cgs units})$$

$$v = 21.89 \times 10^7 \frac{\text{cm}}{\text{sec}} \quad (\text{c.g.s. units}) = 21.89 \times 10^5 \frac{\text{m}}{\text{sec}} \quad (\text{S.I. units})$$

$$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}}{(9.108 \times 10^{-31})(21.89 \times 10^5)} = 3.32 \times 10^{-10} \text{ m} = 3.32 \text{ \AA}$$

ANSWER IS: iii