## Formulas:

(you may remove this page)

$$s^2 = K_{sp}\left(1 + \frac{[H^+]}{K_a}\right)$$

| 1 IA 1A | 2 IIA 2A | 3 IIIB 3B | 4 IVB 4B | 5 VB 5B | 6 VIB 6B | 7 VIIB 7B | 8 --- --- | 9 VIII 8 | 10 --- --- | 11 IB 1B | 12 IIB 2B | 13 IIIA 3A | 14 IVA 4A | 15 VA 5A | 16 VIA 6A | 17 VIIA 7A | 18 VIIIA 8A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H 1.008 | | | | | | | | | | | | | | | | | 2 He 4.003 |
| 3 Li 6.941 | 4 Be 9.012 | | | | | | | | | | | 5 B 10.81 | 6 C 12.01 | 7 N 14.01 | 8 O 16.00 | 9 F 19.00 | 10 Ne 20.18 |
| 11 Na 22.99 | 12 Mg 24.31 | | | | | | | | | | | 13 Al 26.98 | 14 Si 28.09 | 15 P 30.97 | 16 S 32.07 | 17 Cl 35.45 | 18 Ar 39.95 |
| 19 K 39.10 | 20 Ca 40.08 | 21 Sc 44.96 | 22 Ti 47.88 | 23 V 50.94 | 24 Cr 52.00 | 25 Mn 54.94 | 26 Fe 55.85 | 27 Co 58.47 | 28 Ni 58.69 | 29 Cu 63.55 | 30 Zn 65.39 | 31 Ga 69.72 | 32 Ge 72.59 | 33 As 74.92 | 34 Se 78.96 | 35 Br 79.90 | 36 Kr 83.80 |
| 37 Rb 85.47 | 38 Sr 87.62 | 39 Y 88.91 | 40 Zr 91.22 | 41 Nb 92.91 | 42 Mo 95.94 | 43 Tc (98) | 44 Ru 101.1 | 45 Rh 102.9 | 46 Pd 106.4 | 47 Ag 107.9 | 48 Cd 112.4 | 49 In 114.8 | 50 Sn 118.7 | 51 Sb 121.8 | 52 Te 127.6 | 53 I 126.9 | 54 Xe 131.3 |
| 55 Cs 132.9 | 56 Ba 137.3 | 57 La* 138.9 | 72 Hf 178.5 | 73 Ta 180.9 | 74 W 183.9 | 75 Re 186.2 | 76 Os 190.2 | 77 Ir 190.2 | 78 Pt 195.1 | 79 Au 197.0 | 80 Hg 200.5 | 81 Tl 204.4 | 82 Pb 207.2 | 83 Bi 209.0 | 84 Po (210) | 85 At (210) | 86 Rn (222) |

1 H Hydrogen
2 He Helium
3 Li Lithium
4 Be Beryllium
5 B Boron
6 C Carbon
7 N Nitrogen
8 O Oxygen
9 F Fluorine
10 Ne Neon
11 Na Sodium
12 Mg Magnesium
13 Al Aluminum
14 Si Silicon
15 P Phosphorus
16 S Sulfur
17 Cl Chlorine
18 Ar Argon
19 K Potassium
20 Ca Calcium
21 Sc Scandium
22 Ti Titanium
23 V Vanadium
24 Cr Chromium
25 Mn Manganese
26 Fe Iron
27 Co Cobalt
28 Ni Nickel
29 Cu Copper
30 Zn Zinc
31Ga Gallium
32 Ge Germanium
33 As Arsenic
34 Se Selenium
35 Br Bromine
36 Kr Krypton
37 Rb Rubidium
38 Sr Strontium
39 Y Yttrium
40 Zr Zirconium
41 Nb Niobium
42 Mo Molybdenum
43 Tc Technetium
44 Ru Ruthenium
45 Rh Rhodium
46 Pd Palladium
47 Ag Silver
48 Cd Cadmium
49 In Indium
50 Sn Ti
51 Sb Antimony
52 Te Tellurium
53 I Iodine
54 Xe Xenon …
77 Ir Iridium
78 Pt Platinum
79 Au Gold
80 Hg Mercury
81 Tl Thallium
82 Pb Lead

Honors General Chemistry Test 3
Prof. Shattuck, 2014 Name_____

Answer 8 of the following 10 questions. If you answer more than 8 cross out the ones you wish not to be graded, otherwise only the first 8 will be graded. (6 points each)

1. From the following information calculate the $K_f$ for reaction 3.

| | | |
|---|---|---|
| Reaction 1 | $Ag^+ + NH_3 \rightleftarrows Ag(NH_3)^+$ | $K_1 = 1.7\times10^3$ |
| Reaction 2 | $Ag(NH_3)^+ + NH_3 \rightleftarrows Ag(NH_3)_2^+$ | $K_2 = 1.1\times10^7$ |
| Reaction 3 | $Ag^+ + 2\ NH_3 \rightleftarrows Ag(NH_3)_2^+$ | $K_f$ = ? $1.9\times10^{10}$ |

2. Circle the stronger acid in each pair:
(a) $H_2S$, $H_2Se$ (b) $H_3PO_4$, $H_2SO_4$ (c) $HClO_3$, $HClO_4$

3. How do you dissolve the following precipitates? Choose from 0.10 M solutions of HCl, $HNO_3$, $NH_3$, and NaOH. You can use a reagent only once.

(a) $Ba(OH)_2$ add: HCl or $HNO_3$

(b) $Ca_3(PO_4)_2$ add: $HNO_3$ or HCl

(c) $CuI_2$ add: $NH_3$

4. Are 0.100 M aqueous solutions of the following acidic, basic, or neutral?

(a) NaI neutral (b) $NH_4NO_3$ acidic (c) $Na_2S$ basic

5. Is $CaF_2$ more soluble in :(a) pure water, (b) 0.10 M NaF, or (c) 0.10 M $Ca(NO_3)_2$ ?

6. Give the two reactions that show that solid $Zn(OH)_2$ is amphoteric (reacts with both acid and base).

$Zn(OH)_2(s) + 2H^+ \rightarrow Zn^{2+} + 2H_2O(l)$ $Zn(OH)_2$ is basic

$Zn(OH)_2(s) + 2OH^- \rightarrow Zn(OH)_4^{2-}$ $Zn(OH)_2$ is Lewis acid

7. Calculate the pH of a 0.0100 M solution of $NaHCO_3$. The acid dissociation constants are $K_{a,1} = 4.5\times10^{-7}$ and $K_{a,2} = 4.7\times10^{-11}$.

$H_2CO_3 \rightleftarrows 2H^+ + CO_3^{2-}$ $K_q = K_{a1}K_{a2} = \dfrac{[H^+]^2[CO_3^{2-}]}{[H_2CO_3]}$

to a good approximation $[CO_3^{2-}] \approx [H_2CO_3]$

$[H^+]^2 = K_{a1}K_{a2}$ $[H^+] = \sqrt{K_{a1}K_{a2}}$ or

$pH = \dfrac{pK_{a1} + pK_{a2}}{2} = \dfrac{6.347 + 10.328}{2} = 8.34$

8. For the following reactions, does the equilibrium position lie to the left or right?

(a) $CN^- + H_2O \rightleftarrows HCN + OH^-$ ← (strong base) left

(b) $CN^- + H_3O^+ \rightleftarrows HCN + H_2O$ → right

(strong acid)

9. For the following reactions, indicate the conjugate acid–base pairs. Make sure to label the acid and base in each conjugate pair as the acid or base.

(a) $HPO_4^{2-} + H_2O \rightleftarrows H_2PO_4^- + OH^-$

b a a b

(b) $HCN + H_2O \rightleftarrows CN^- + H_3O^+$

a b b a

10. Name the following compounds:

(a) $Ca(NO_3)_2$ calcium nitrate

(b) $H_3PO_3$ phosphorus acid

(c) $(NH_4)_2SO_3$ ammonium sulfite

**Part II.**

Answer 2 of the following 3 questions. If you answer more than 2 cross out the one you wish not to be graded, otherwise only the first 2 will be graded. (12 points each)

11. You need to prepare 100.0 mL of a pH = 4.00 buffer solution using 0.100 M benzoic acid ($pK_a = 4.20$, $K_a = 6.31 \times 10^{-5}$) and 0.220 M sodium benzoate. How much of each solution should be mixed to prepare this buffer? $pH = 4.00$ $[H^+] = 1.0 \times 10^{-4}$ M

buffer $[H^+] = K_a \frac{C_A}{C_B}$ $\frac{C_A}{C_B} = \frac{[H^+]}{K_a} = \frac{1.0 \times 10^{-4} M}{6.31 \times 10^{-5} M} = 1.585$

$\frac{C_A}{C_B} = \frac{n_A/V}{n_B/V} = \frac{n_A}{n_B} = \frac{V_A(0.100M)}{V_B(0.220M)} = 1.585$

giving $\frac{V_A}{V_B} = 3.487$ with $V_A + V_B = 100.0$ mL and

$V_A = 3.487\, V_B$ so $3.487\, V_B + V_B = 100.0$ mL

solving for $V_B = 22.3$ mL

and $V_A = 100.0$ mL $- V_B = 77.71$ mL

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Check: $[H^+] = 6.31 \times 10^{-5}$ M $\frac{(77.71 \text{ mL})(0.100 M)}{(22.3 \text{ mL})(0.220 M)} = 1.00 \times 10^{-4}$ M

12. Calculate the pH of a 0.100 M $NH_3$ solution if $K_b = 1.8\times10^{-5}$ M . Show the reaction that determines the pH.

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

$0.100-x \qquad x \qquad x$

$K_b = 1.8\times10^{-5} = \frac{x^2}{0.100-x} \qquad x = [OH^-] = \sqrt{C_B K_b} = \sqrt{0.100\,M \; 1.8\times10^{-5}}$

$= 1.34\times10^{-3}\,M$

pOH = 2.872 and pH = 11.13

13. Calculate the solubility of $PbI_2$ in pure water if $K_{sp} = 8.7\times10^{-9}\ M^3$.

$PbI_2(s) \rightleftharpoons Pb^{2+} + 2I^-$

$x \qquad 2x$

$K_{sp} = 8.7\times10^{-9}\,M^3 = [Pb^{2+}][I^-]^2 = 4x^3$

$x = s = [Pb^{2+}] = 1.296\times10^{-3}\,M \approx 1.3\times10^{-3}\,M$

**Part III.**

Answer 2 of the following 3 questions. If you answer more than 2 cross out the one you wish not to be graded, otherwise only the first 2 will be graded. (14 points each)

14. Calculate the pH at the equivalence point of a titration of 30.0 mL of 0.100 M HCN with 0.100 M NaOH. For HCN, $K_a = 4.0\times10^{-8}$ M . Show the reaction that determines the pH.

titration reaction: $HCN + OH^- \rightarrow CN^- + H_2O$

at equivalence point: $CN^- + H_2O \overset{K_b}{\rightleftharpoons} HCN + OH^-$

$0.05-x \qquad x \qquad x$

initial concentration diluted:

$K_b = \frac{[HCN][OH^-]}{[CN^-]} = \frac{K_w}{K_a} = 2.5\times10^{-7} = \frac{x^2}{0.05-x}$

$x = [OH^-] = \sqrt{C_B K_b} = \sqrt{0.050 \; 2.5\times10^{-7}} = 1.118\times10^{-4}\,M$

pOH = 3.952 pH = 10.05

15. A 0.170-mole quantity of $NiCl_2$ is added to a liter of 1.20 M $NH_3$ solution. What is the concentration of $Ni^{2+}$ ions at equilibrium. Assume the formation constant of $Ni(NH_3)_6^{2+}$ is $5.5 \times 10^8$.

$Ni(NH_3)_6^{2+} \overset{K_d}{\rightleftharpoons} Ni^{2+} + 6NH_3$ $\quad K_d = 1/K_f = 1.818 \times 10^{-9}$

| | | | |
|---|---|---|---|
| initial | 0.170 M | | $1.20 - 6(0.170) = 0.180$ |
| equil. | $0.170 - x$ | $+x$ | $0.18 + x$ |

$$K_d = \frac{[Ni^{2+}][NH_3]^6}{[Ni(NH_3)_6^{2+}]} = \frac{x(0.18+x)^6}{0.170 - x} \approx \frac{x(0.180)^6}{0.170}$$

$$x = [Ni^{2+}] = 9.1 \times 10^{-6}\ M$$

16. Calculate the solubility of $CaCO_3$ in a lake buffered at pH = 5.60. The equilibrium constants are $K_{a2} = 5.6 \times 10^{-11}$ and $K_{sp} = 4.5 \times 10^{-9}$.

$$S^2 = K_{sp}\left(1 + \frac{[H^+]}{K_{a2}}\right)$$

$pH = 5.60$

$[H^+] = 2.512 \times 10^{-6}\ M$

$$S^2 = 4.5 \times 10^{-9}\left(1 + \frac{2.512 \times 10^{-6}\ M}{5.6 \times 10^{-11}\ M}\right)$$

$S^2 = 2.0186 \times 10^{-4}\ M^2$

$S = 0.0142\ M$

$S = 0.014\ M$