Exam 3
CHEM 1142
Fall 2008

Name: KEY

Multiple choice. Circle the best response. [3 pts. each]

Q1. Given the following slightly soluble salts and solubility-product constants, which salt would be most soluble in pure water?

Most Soluble = a
Least Soluble = c

a) AgCl: $K_{sp} = 1.8 \times 10^{-10}$
b) AgBr: $K_{sp} = 5.0 \times 10^{-15}$
c) AgI: $K_{sp} = 8.5 \times 10^{-17}$
d) AuCl: $K_{sp} = 2.0 \times 10^{-13}$

Q2. What is the correct expression for the solubility product constant for calcium phosphate?

$Ca_3(PO_4)_{2(s)} \rightleftharpoons 3Ca^{2+}_{(aq)} + 2PO_4^{3-}_{(aq)}$; K_{sp}

a) $K_{sp} = [Ca^{2+}][PO_4^{3-}]$
b) $K_{sp} = [Ca^{2+}]^2[PO_4^{3-}]^2$
c) $K_{sp} = [Ca^{2+}]^2[PO_4^{3-}]^2$
d) $K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2$
e) The correct response is not given.

Q3. Calculate the pH of a buffer prepared by mixing 0.10 mol of sodium formate and 0.05 mol of formic acid in 1.0 L of solution. [Formic Acid: HCO_2H: $K_a = 1.8 \times 10^{-4}$]

$pH = pK_a + \log\frac{[base]}{[acid]} = 3.74 + \log\left(\frac{0.10\,M}{0.05\,M}\right) = 4.045$

$pK_a = -\log(K_a) = 3.74$

a) 1.8×10^{-4}
b) 3.44
c) 4.05
d) 5.31
e) none of these

Q4. Hypochlorite ion (OCl^-) is the conjugate base of hypochlorous acid (HOCl, $K_a = 3.5 \times 10^{-8}$). What is the value of the base ionization equilibrium constant, K_b, for hypochlorite ion?

$K_a \cdot K_b = K_w \Rightarrow K_b = K_w/K_a = 1.0\times10^{-14} \div 3.5\times10^{-8} = 2.85\times10^{-7}$

a) 3.5×10^{-22}
b) 3.5×10^{-8}
c) 2.9×10^{-7}
d) 2.9×10^{7}
e) 4.7×10^{9}

Q5. A buffer can be prepared by mixing:

a) a strong acid and its conjugate base.
b) a strong base and its conjugate acid.
c) a weak acid and its conjugate base.
d) a weak acid and a strong acid.
e) all responses above are correct.

Q6. The ***iodide*** concentration of a saturated solution of PbI_2 is 2.4×10^{-3} M. What is the K_{sp} for lead iodide?

$PbI_{2(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2I^-_{(aq)}$

$2.4\times10^{-3}\,M \rightarrow 1.2\times10^{-3}\,M$

$K_{sp} = [Pb^{2+}][I^-]^2 = 6.9\times10^{-9}$

a) 2.4×10^{-3}
b) 2.9×10^{-6}
c) 1.4×10^{-8}
d) 6.9×10^{-9}
e) 1.7×10^{-9}

Q7. Identify the conjugate base of HPO_4^{2-} in the following reaction:

$$HCO_3^- + HPO_4^{2-} \rightleftharpoons H_2CO_3 + PO_4^{3-}$$

a) H_2O
b) HCO_3^-
c) H_2CO_3
d) PO_4^{3-}
e) None of these.

Q8. The OH^- concentration in a 1.0×10^{-3} M $Ba(OH)_2$ solution is
a) 0.50×10^{-3} M b) 1.0×10^{-3} M (c) 2.0×10^{-3} M
d) 0.01 M e) 0.020 M.

$Ba(OH)_2 \rightarrow Ba^{2+} + 2OH^-$
1.0×10^{-3} $\quad 2.0\times10^{-3}$

Q9. Calculate the pH of a beer in which the hydrogen ion concentration is 6.3×10^{-5} M.
(a) 4.20 b) 4.82 c) 5.63 d) 9.83 e) 14.04

$pH = -\log[H^+]$

Q10. Calculate the pH of a 6.71×10^{-2} M NaOH solution.
(a) 12.83 b) 2.17 c) 11.82 d) 6.71 e) 1.17

$NaOH \rightarrow Na^+ + OH^-$
$\uparrow 6.71\times10^{-2}$
$pOH = -\log[OH^-] = 1.17$

Q11. Which one of the following salts will form an acidic solution upon dissolving in water?
a) KBr b) NaF (c) NH_4I d) KOH e) NaCN

$pH = 14 - pOH$
$= 12.83$

Short Response. Show *all* work to receive credit.

NH_4^+ = conj. acid of a weak base (NH_3)
$\Rightarrow$ acidic

Q12. [5 pts.] What is the pOH of a 0.025 M solution of HCl(aq) at 25 °C?

$HCl \rightarrow H^+ + Cl^-$
$\underset{0.025M}{\quad}$

$pH = -\log[H^+] = 1.60$
$pOH = 14.00 - pH = \underline{\underline{12.40}}$.

Q13. [8 pts.] A 0.065 M aqueous solution of pyruvic acid ($HC_3H_3O_3$, a weak monoprotic acid) has a pH of 3.10 at 25 °C. What is K_a for pyruvic acid?

$HC_3H_3O_{3(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_3H_3O_3^-{}_{(aq)}$

I	0.065	—	≈ 0	0
C	$-x$	—	$+x$	$+x$
E	$(0.065-x)$	—	(x)	(x)

$K_a = \dfrac{[H_3O^+][C_3H_3O_3^-]}{[HC_3H_3O_3]} = \dfrac{x^2}{0.065 - x}$

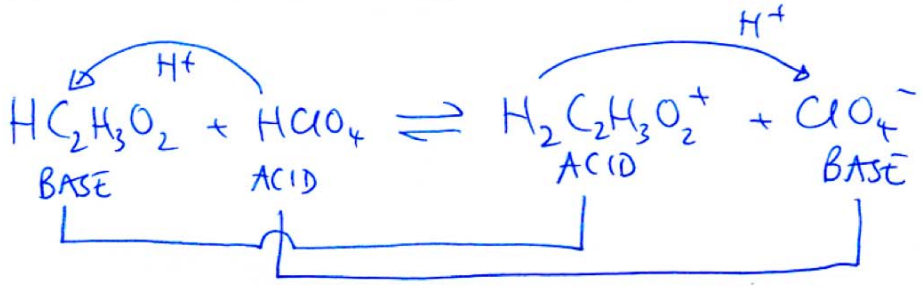
$pH = -\log[H^+] \Rightarrow [H^+] = 10^{-pH} = 10^{-3.10} = 7.94\times10^{-4}\,M = x$!

$\Rightarrow K_a = \dfrac{(7.94\times10^{-4})^2}{0.065 - 7.94\times10^{-4}} = 9.83\times10^{-6}$.

Q14. [6 pts.] Consider the chemical reaction:

$$HC_2H_3O_2 + HClO_4 \rightleftharpoons H_2C_2H_3O_2^+ + ClO_4^-$$

Identify (and label as acid/base) both conjugate acid-base pairs.



Q15. [4 pts.] State the Lewis and Brønstëd definitions of an acid and a base.

Lewis	Brønstëd
Acid: e^- acceptor	Acid: H^+ donor
Base: e^- donor	Base: H^+ acceptor

Q16. [7 pts.] K_w is equal to 4.5×10^{-12} at 205 °C. What pH corresponds to a neutral solution at this temperature?

$$2H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

I	___	0	0
C	"-2x"	+x	+x
E	___	(x)	(x)

$K_w = [H_3O^+][OH^-] = x^2$

$\Rightarrow x = \sqrt{K_w} = \sqrt{4.5\times10^{-12}} = 2.12\times10^{-6}$

$[H_3O^+] = x = 2.12\times10^{-6}\,M$

$\Rightarrow pH = -\log[H_3O^+) = \underline{\underline{5.67}}$

Q17. [5 pts.] Calculate the pH of a 4.2×10^{-4} M solution of KOH(aq).

$$KOH \longrightarrow K^+_{(aq)} + OH^-_{(aq)}$$

$4.2\times10^{-4}M \longrightarrow 4.2\times10^{-4}M \quad 4.2\times10^{-4}M$

$pOH = -\log[OH^-] = 3.38$

$pH = 14.00 - pOH = \underline{\underline{10.62}}$

Q18. [8 pts.] What is the molar solubility of strontium sulfate, $SrSO_4$, in 0.15 M sodium sulfate, Na_2SO_4(aq)? $K_{sp}(SrSO_4) = 2.5 \times 10^{-7}$

(common-ion effect)

$$Na_2SO_4 \longrightarrow 2Na^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$

$0.15M \longrightarrow 0.30M \quad 0.15M$.

$$SrSO_{4(s)} \rightleftharpoons Sr^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$$

I	___	0	0.15
C	"-s"	+s	+s
E	___	(s)	(0.15+s)

$K_{sp} = [Sr^{2+}][SO_4^{2-}] \Rightarrow 2.5\times10^{-7} = (s)(0.15+s)$

$\Rightarrow 2.5\times10^{-7} \approx (s)(0.15)$

$\Rightarrow s = \dfrac{2.5\times10^{-7}}{0.15} = 1.67\times10^{-6}\,M$

Q19. [12 pts.] What is the pH of the solution obtained from mixing 35 mL of 0.10 M acetic acid, $HC_2H_3O_2(aq)$ with 55 mL of 0.15 M sodium acetate, $NaC_2H_3O_2(aq)$? $K_a(HC_2H_3O_2) = 1.7 \times 10^{-5}$.

We have a buffer, since 2 components are weak acid + conj. base
$HC_2H_3O_2$ + $C_2H_3O_2^-$

Vol. changes on mixing ⇒ let's use # moles.

#mol $HC_2H_3O_2$

$$35\,mL \left| \frac{1\,L}{1000\,mL} \right| \frac{0.10\,mol\,HC_2H_3O_2}{1\,L} = 0.0035\,mol\ HC_2H_3O_2$$

#mol $C_2H_3O_2^-$

$NaC_2H_3O_2 \longrightarrow Na^+ + C_2H_3O_2^-$

$$55\,mL \left| \frac{1\,L}{1000\,mL} \right| \frac{0.15\,mol\,NaC_2H_3O_2}{1\,L} \left| \frac{1\,mol\,C_2H_3O_2^-}{1\,mol\,NaC_2H_3O_2} \right. = 0.00825\,mol\,C_2H_3O_2^-$$

Henderson-Hasselbalch

$$pH = pK_a + \log\frac{[base]}{[acid]} = 4.77 + \log\left(\frac{0.00825\,mol\,C_2H_3O_2^- / 0.090\,L}{0.0035\,mol\,HC_2H_3O_2 / 0.090\,L}\right)$$

tot vol = 35 mL + 55 mL = 90 mL = 0.090 L

$-\log(K_a) = 4.77$

$$= 4.77 + \log(2.357)$$

$$= 5.14$$

Q20. [12 pts.] Calculate the pH of a solution obtained by mixing 10.0 mL of 0.150 M KOH(aq) with 35.0 mL of 0.135 M acetic acid, $HC_2H_3O_2$(aq). $K_a(HC_2H_3O_2) = 1.7 \times 10^{-5}$.

KOH is a STRONG base! Vol's change ⇒ best to work w/ moles.

Acetic acid is a WEAK acid! tot. vol ≈ 10.0 + 35.0 = 45.0 mL = 0.0450 L

⇒ Start with a complete neutralization rxn (1), end up with eqm (2).

(1) $KOH \rightarrow K^+ + OH^-$

$$\#\text{mol } OH^- \quad \frac{10.0\text{mL}}{1000\text{mL}} \left| \frac{1\text{L}}{1\text{L}} \right| \frac{0.150\text{mol KOH}}{1\text{L}} \left| \frac{1\text{mol } OH^-}{1\text{mol KOH}} \right| = 0.00150\text{mol } OH^-$$

rxn: $HC_2H_3O_{2(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)} + C_2H_3O_2^-{}_{(aq)}$

? 0.00150mol — 0

$$\#\text{mol } HC_2H_3O_2 \quad \frac{35.0\text{mL}}{1000\text{mL}} \left| \frac{1\text{L}}{1\text{L}} \right| \frac{0.135\text{mol } HC_2H_3O_2}{1\text{L}} = 0.004725\text{mol } HC_2H_3O_2$$

XS LR

⇒ rxn (1): $HC_2H_3O_{2(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)} + C_2H_3O_2^-{}_{(aq)}$

	$HC_2H_3O_2$	OH^-		$C_2H_3O_2^-$
I	0.004725mol	0.00150mol	—	0
C	−0.00150	−0.00150	—	+0.00150
E	0.003225mol	0	—	0.00150mol

(2) Now we have weak acid + conj. base! Could write K_a eqm + Solve ICE chart. But... since this is a buffer, let's use Henderson-Hasselbalch eqn!

$$pH = pK_a + \log\frac{[\text{base}]}{[\text{acid}]} = 4.77 + \log\left(\frac{0.00150\text{mol}/0.0450\text{L}}{0.003225\text{mol}/0.0450\text{L}}\right)$$

tot. vol.

$-\log(K_a)$ = 4.77

⇒ $pH = 4.77 + \log(0.465)$

⇒ $pH = \underline{4.44}$

BONUS Questions:

A) Given the thermochemical equation:
$C_4H_8O_2(s) + 5O_2(g) \rightarrow 4CO_2(g)+4H_2O(l)$; $\Delta H^\circ = 3370$ kJ·mol^{-1}

How much heat is absorbed/released when 34.2 g of $C_4H_8O_2$ reacts? Is the process exothermic or endothermic?

$C_4H_8O_2$

$4\times C = 4\times 12.01$
$8\times H = 8\times 1.01$
$2\times O = 2\times 16.00$
88.12

$$\frac{34.2\text{ g } C_4H_8O_2 \mid 1\text{ mol } C_4H_8O_2 \mid 3370\text{ kJ}}{88.12\text{ g } C_4H_8O_2 \mid 1\text{ mol } C_4H_8O_2} = +1310\text{ kJ}$$

(endothermic)

B) Calculate the osmotic pressure of a solution of 0.0350 M $CaCl_2$(aq) at a temperature of 24 °C. State any assumptions you are making.

$$\Pi = i \cdot M \cdot R \cdot T = 3 \times 0.0350\text{ M} \times 0.08206 \frac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}} \times 297\text{ K} = 2.56\text{ atm}$$

M = mol/L

$CaCl_2 \rightarrow \underbrace{Ca^{2+} + 2Cl^-}$

$i = 3$

Assuming $i = 3$

@ high concs, get ion-pairing which reduces i from its theoretical value.