CHM 152/54 Exam 2-V1 SPRING 2004 Name: Key

1. What is the equilibrium expression, K_c, for the following reaction?

$Ca_3(PO_4)_2(s) \leftrightharpoons 3Ca^{2+}(aq) + 2PO_4^{3-}(aq)$

a) $K_c = [Ca_3(PO_4)_2] / [Ca^{2+}][PO_4^{3-}]^2$
b) $K_c = [Ca^{2+}][PO_4^{3-}]$
c) $K_c = [Ca^{2+}]^3[PO_4^{3-}]^2/[Ca_3(PO_4)_2]$
d) $K_c = [Ca^{2+}]^3[PO_4^{3-}]^2$
e) $K_c = [3Ca^{2+}]^3[2PO_4^{3-}]^2/[Ca_3(PO_4)_2]$

$K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2$

2. A 1.00 liter flask contained 0.24 mol NO_2 at 700 K. which decomposed according to the following equation. When equilibrium was achieved, 0.14 mol NO was present. Calculate K_c.

$2NO_2(g) \leftrightharpoons 2NO(g) + O_2(g)$

a) 0.098
b) 0.14
c) 1.1×10^{-2}
d) 5.7×10^{3}
e) 9.6×10^{-3}

$K_c = \frac{[NO]^2[O_2]}{[NO_2]^2}$

	$2NO_2$	$\leftrightharpoons$	$2NO$	+	O_2
I	0.24		0		0
C	$-2x$		$+2x$		$+x$
E	$0.24-2x$		$2x$		x

$2x = 0.14 \quad x = 0.07$

$K_c = \frac{(0.14)^2(0.07)}{(0.24-0.14)^2}$

$K_c = 0.137$

3. A mixture of 0.40 moles of H_2 and 0.40 moles of I_2 is placed in a 1.00 liter container at 650°C and allowed to reach equilibrium according to the following equation. The equilibrium constant is 64. Calculate the concentrations of all species present at equilibrium.

$H_2(g) + I_2(g) \leftrightharpoons 2HI(g) \quad K = 64 = \frac{[HI]^2}{[H_2][I_2]}$

a) $[H_2] = 0.13 \quad [I_2] = 0.13 \quad [HI] = 0.53$
b) $[H_2] = 0.040 \quad [I_2] = 0.040 \quad [HI] = 0.32$
c) $[H_2] = 0.080 \quad [I_2] = 0.080 \quad [HI] = 0.64$
d) $[H_2] = 0.32 \quad [I_2] = 0.32 \quad [HI] = 0.24$
e) $[H_2] = 0.015 \quad [I_2] = 0.015 \quad [HI] = 0.12$

	H_2	+	I_2	$\rightleftharpoons$	$2HI$
I	0.40		0.40		0
C	$-x$		$-x$		$+2x$
E	$0.40-x$		$0.40-x$		$2x$

$64 = \frac{(2x)^2}{(0.40-x)^2}$ "perfect square"

$8 = \frac{2x}{0.40-x} \Rightarrow 3.2 = 10x$

$x = 0.32$

4. Consider the reaction $2A(g) \leftrightharpoons B(g)$ where $K_c = 0.5$ at the temperature of the reaction. If 2.0 moles of A and 2.0 moles of B are introduced into a 1.00 liter flask, what change in concentrations (if any) would occur in time?

a) [A] increases and [B] increases
b) [A] increases and [B] decreases
c) [A] decreases and [B] increases
d) [A] decreases and [B] decreases
e) [A] and [B] remain the same

$2A(g) \rightleftharpoons B(g) \quad K_c = 0.5$

2 2

$K_c = \frac{[B]}{[A]^2}$

$Q = \frac{[2]}{[2]^2} = 0.5$

$Q = K_c$

5. Exactly 0.50 mole of sulfur trioxide, 0.10 mole of sulfur dioxide, 0.20 mole of nitrogen monoxide and 0.30 mole nitrogen dioxide are sealed in a 1.0-L flask at 1500°C. The equilibrium constant K_c is 0.24 for the following reaction.

$SO_3(g) + NO(g) \leftrightharpoons SO_2(g) + NO2(g) \quad K_c = 0.24$

When equilibrium is achieved, what changes in concentrations of SO_3 and NO will be observed?

a) [SO_3] increases; [NO] increases
b) [SO_3] increases; [NO] decreases
c) [SO_3] decreases; [NO] decreases
d) [SO_3] decreases; [NO] increases
e) all concentrations remain the same

$SO_3 + NO \rightleftharpoons SO_2 + NO_2$
I 0.50 0.20 0.10 0.30

$Q = \frac{[0.10][0.30]}{[0.50][0.20]}$

$Q = 0.3$

$Q > K_c$ so shift ←

6. In which of the following reactions does a decrease in the volume of the container increase the concentration of the products? Assume constant temperature.

a) $SO_2Cl_2(g) \leftrightharpoons SO_2(g) + Cl_2(g)$
b) $C(s) + H_2O(g) \leftrightharpoons CO(g) + H_2(g)$
c) $2SO_3(g) \leftrightharpoons 2SO_2(g) + O_2(g)$
d) $I_2(g) + Cl_2(g) \leftrightharpoons 2ICl(g)$
e) $2NO + Br_2(g) \leftrightharpoons 2NOBr(g)$

3 mol(g) → 2 mol(g)

7. A flask contains the following system at equilibrium:

$PbCl_2(s) \leftrightharpoons Pb^{2+}(aq) + 2Cl^-(aq)$

If solid NaCl is added to the system, what change (if any) will be observed?

a) more $PbCl_2$ will dissolve
b) more $PbCl_2$ will precipitate
c) more Pb^{2+} will be in solution
d) fewer Cl^- will be in solution
e) no change will be observed

$K_{sp} = [Pb^{2+}][Cl^-]^2$

then ↓ if ↑

8. A flask contains the following system at equilibrium:

$Mg(OH)_2(s) \leftrightharpoons Mg^{2+}(aq) + 2OH^-(aq)$

Which of the following reagents could be added to increase the solubility of $Mg(OH)_2$?

a) NaCl
b) NaOH
c) HCl
d) H_2O
e) $MgCl_2$

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

$K_{sp} = [Mg^{2+}][OH^-]^2$ (↑ ↓)

9. Which of the following statements concerning equilibrium is true?

a) Catalysts are an effective means of changing the position of an equilibrium.
b) The concentration of the products equals the concentration of reactions for a reaction at equilibrium.
c) The equilibrium constant may be expressed in pressure terms or concentration terms for any reaction.
d) When two opposing processes are proceeding at the same rate, the system is at equilibrium.
e) A system at equilibrium cannot be disturbed.

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10. In the equation, $NH_4^+(aq) + H_2O(l) \leftrightharpoons NH_3(aq) + H_3O^+(aq)$

Acid Base C.B C.A

a) NH_4^+ is an acid and NH_3 is its conjugate base.
b) H_2O is an acid and H_3O^+ is its conjugate base.
c) NH_3 is an acid and H_3O^+ is its conjugate base.
d) H_2O is an acid and NH_4^+ is its conjugate base.
e) NH_3 is an acid and NH_4^+ is its conjugate base.

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11. The conjugate base of HCO_3^- is

a) CO_3^{2-}
b) H_2CO_3
c) H_3O^+
d) OH^-
e) H_2O

Acid $- H^+ =$ C.B.

12. At 50°C the water ionization constant, K_w, is 5.48×10^{-14}. What is the $[H_3O^+]$ in neutral water at 50°C?

a) 5.48×10^{-7}
b) 2.34×10^{-7}
c) 1.00×10^{-7}
d) 5.48×10^{-14}
e) 4.27×10^{-13}

$[H^+][OH^-] = K_w$ and $[H^+] = [OH^-]$ ⇒

$[H^+] = [OH^-] = \sqrt{K_w} = \sqrt{5.48 \times 10^{-14}}$

13. What is the pH of a 0.0813 M HNO_3 solution at 25°C?

a) 0.813
b) 0.910
c) 1.090
d) 1.813
e) 1.870

Strong Acid $[H^+]$ = Conc of acid

$pH = -\log(0.0813) =$

14. What is the pH of a 1.86 M $CH_3CH_2CO_2H$ solution at 25°C? $K_a = 1.3 \times 10^{-5}$

a) 4.92
b) 4.88
c) 2.42
d) 2.31
e) 2.08

Weak acid

$CH_3CH_2CO_2H \rightleftharpoons H^+ + CH_3CH_2CO_2^-$

	$CH_3CH_2CO_2H$	H^+	$CH_3CH_2CO_2^-$
I	1.86	0	0
C	$-x$	$+x$	$+x$
E	$1.86 - x$	x	x

$K_a = \frac{[H^+][CH_3CH_2CO_2^-]}{[CH_3CH_2CO_2H]}$

$1.3 \times 10^{-5} = \frac{x^2}{1.86 - x}$

5. What is the pH of a 0.0144 M $Ca(OH)_2$ solution at 25°C?

a) 1.54
b) 1.84
c) 10.84
d) 12.16
e) 12.45

Strong Base

$Ca(OH)_2(s) \rightarrow Ca^{2+} + 2OH^-$

$[OH^-] = 2(0.0144) = 0.0288$

$pOH = 1.54$

$pH = 12.45$

$x = 0.004917 = [H^+]$

$pH = -\log(H^+)$

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16. What is the pH of a 0.0443 M ammonia (NH_3) solution at 25°C? $K_b = 1.8 \times 10^{-5}$

wk. base

a) 3.05
b) 6.10
c) 9.25
d) 10.95
e) 12.64

	NH_3	+ H_2O ⇌	NH_4^+	+ OH^-
I	0.0443		0	0
C	−x		+x	+x
E	0.0443−x		x	x

$K_b = 1.8 \times 10^{-5} = \frac{x^2}{0.0443 - x}$

$x = 3.4 \times 10^{-4} = [OH^-]$

$pOH = 3.049$ $pH = 10.95$

17. The pH of a 2.28 M solution of a weak acid is 5.21 at 25°C. What is K_a for the weak acid?

a) 2.1×10^{-5}
b) 6.2×10^{-6}
c) 8.8×10^{-9}
d) 4.8×10^{-10}
e) 1.7×10^{-11}

$HA_{(aq)} \rightleftharpoons H^+ + A^-$ $K_a = \frac{[H^+][A^-]}{[HA]}$

$[H^+] = 10^{-5.21} = 6.16 \times 10^{-6}$ $K_a = \frac{(6.16 \times 10^{-6})^2}{(2.28 - 6.16 \times 10^{-6})}$

$K_a = 1.7 \times 10^{-11}$

18. Three weak acids have the formulas and K_a values listed.

Formic acid	CHO_2H	1.8×10^{-4}
Cyanic Acid	HOCN	3.5×10^{-4}
Chloroacetic Acid	$C_2H_2ClO_2H$	1.4×10^{-3}

weakest Acid

Which of the following is the strongest base?

a) $C2H_2ClO_2^-$
b) OCN^-
c) HCO_2^-
d) H_2O
e) H_3O^+

weakest acid gives strongest conj BASE.

19. Of the salts, KCH_3CO_2, NH_4Cl, KBr, and NH_4NO_3, how many would form an acidic aqueous solution?

S W W S S S W S

a) four
b) three
c) two
d) one
e) zero (none form basic solutions)

$NH_4^+ + H_2O \rightleftharpoons NH_4OH + H^+$

or $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

20. If you mix equal molar quantities of KOH and HNO_3, the resulting solution will be

S S S S

a) acidic because a small amount of KNO_3 is present.
b) acidic because a small amount of H_3O^+ is present.
c) basic because a small amount of OH^- is present.
d) basic because a small amount of KNO_3 is present.
e) neutral.