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CHM152/54 Exam 2 100 Pts Fall 2004 Name: Key

MULTIPLE CHOICE

1. Given that the K_a for gallic acid, ($HC_7H_5O_5$) is 4.57×10^{-3}, what is the K_b for the gallate ion ($NaC_7H_5O_5$)? T = 25°C
   a) 4.57×10^{-3}
   b) 2.19×10^{-12}
   c) 5.43×10^{-5}
   d) 7.81×10^{-6}
   e) 2.19×10^{2}

$K_a K_b = 10^{-14}$

2. The pH of a 0.10 M solution of a weak base is 9.82. What is the K_b for this base?
   a) 2.1×10^{-4}
   b) 4.3×10^{-8}
   c) 8.8×10^{-8}
   d) 6.6×10^{-4}
   e) 2.0×10^{-5}

pOH = 4.18

$B + H_2O \rightleftharpoons HB^+ + OH^-$

	B	HB^+	OH^-
	0.10	0	0
	−x	+x	+x
	0.10 − x	x	x

$x = 10^{-4.18} = 6.61 \times 10^{-5}$

$K_b = \frac{x^2}{0.10 - x}$

$K_b = \frac{(6.61 \times 10^{-5})^2}{0.10 - 6.61 \times 10^{-5}}$

$K_b = 4.3 \times 10^{-8}$

3. Consider the following reaction:

$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

Initially, 0.84 mol of $PCl_5(g)$ was placed in a 1.0 L flask. At equilibrium, 0.72 mol of $PCl_5(g)$ was present. The value of K_c for this reaction at this temperature is _____.
   a) 0.62
   b) 2.0×10^{-2}
   c) 0.72
   d) 0.12
   e) 0.60

$PCl_5 \rightleftharpoons PCl_3 + Cl_2$

	PCl_5	PCl_3	Cl_2
I	0.84	0	0
C	−x	+x	+x
E	0.84 − x	x	x

$0.84 - x = 0.72 \quad x = 0.12$

$K_c = \frac{(0.12)^2}{0.72}$

$K_c = 0.02$

4. What is the pH of a 2.5 M solution of phosphoric acid? ($Ka_1 = 7.5 \times 10^{-3}$, $Ka_2 = 6.2 \times 10^{-8}$, $Ka_3 = 4.2 \times 10^{-13}$)
   a) 1.8
   b) 0.40
   c) 2.5
   d) 0.88
   e) 0.13

$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^-$ ← Controls pH

	H_3PO_4	H^+	$H_2PO_4^-$
I	2.5	0	0
C	−x	+x	+x
E	2.5 − x	x	x

$K_{a_1} = \frac{[x]^2}{2.5 - x}$

$7.5 \times 10^{-3} = \frac{x^2}{2.5}$

$x = 0.13$

5. For the endothermic reaction
heat + $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$
   only _____ would favor shifting the equilibrium position to form more CO_2 gas.
   a) increasing the system temperature
   b) decreasing the system temperature
   c) increasing the system pressure
   d) increasing both the system temperature and the system pressure
   e) both decreasing the system temperature and increasing the system pressure

heat is a "reactant"

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6. At equilibrium, _____.
   a) all chemical processes have ceased.
   b) the rate of the forward reaction equals that of the reverse.
   c) the rate constant for the forward reaction equals that of the reverse.
   d) both the rate of the forward reaction equals that of the reverse and the rate constant for the forward reaction equals that of the reverse.
   e) none of the above

7.

Acid	K_a
HOAc	1.8×10^{-5}
$HCHO_2$	1.8×10^{-4}
HClO	3.0×10^{-8}
HF	6.8×10^{-4}

weakest acid has strongest Conj. Base

$K_a K_b = 10^{-14}$

Which one of the following is the strongest base?
   a) OAc^-
   b) CHO_2^-
   c) ClO^-
   d) F^-
   e) OAc^- and CHO_2^-

8. Consider the following incomplete table of data for the equilibrium between dinitrogen tetroxide and nitrogen dioxide.

Exp #	Equilibrium N_2O_4 Concentration	Equilibrium NO_2 Concentration
1	0.00140 *M*	0.0172 *M*
2	0.00452	?
3	0.00280	0.0243

From the information in the table, determine the value of the missing NO_2 concentration at equilibrium.
   a) 0.0486
   b) 9.54×10^{-4}
   c) 0.0814
   d) 0.115
   e) 0.0309

$N_2O_4(g) \rightleftharpoons 2NO_2 \quad K_c = \frac{[NO_2]^2}{[N_2O_4]}$

$0.211 = \frac{[NO_2]^2}{0.00415}$ then $K_c = 0.211$ (use 1 or 3)

9. What is the concentration (in M) of hydronium ions in a solution at 25°C with a hydroxide ion concentration of 2.31×10^{-4} M ?
   a) 4.33×10^{-11}
   b) 2.31×10^{10}
   c) 9.72×10^{-4}
   d) 1.01×10^{-5}
   e) 2.31×10^{-18}

$[H_3O^+][OH^-] = 10^{-14}$

$[H_3O^+] = 10^{-14} / 2.31 \times 10^{-4} = 4.33 \times 10^{-11}$

10. Calculate the pH of a solution made by dissolving 1.87 g of sodium caproate, $NaC_6H_{11}O_2$ (molar mass = 138.15) in water and diluting to a total volume of 500.0 mL. For the caproate ion, $K_b = 7.58 \times 10^{-10}$.
   a) 5.344
   b) 8.656
   c) 5.494
   d) 8.505
   e) 4.53×10^{-6}

Chemistry $NaC_6H_{11}O_2 \xrightarrow{H_2O} Na^+ + C_6HO_2^-$ weak base

$C_6HO_2^- + H_2O \rightleftharpoons HC_6HO_2 + OH^-$

	$C_6HO_2^-$	HC_6HO_2	OH^-
I	0.0271	0	0
C	$-x$	$+x$	$+x$
E	$0.0271 - x$	x	x

$K_b = \frac{x^2}{0.0271 - x}$ (Try to drop C)

$x = 4.530 \times 10^{-6}$

$pOH = 5.344$

$pH = 8.656$

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11. The equilibrium expression

$$K_c = \frac{[H_2]^2[O_2]}{[H_2O]^2}$$

$2H_2O \rightleftharpoons 2H_2 + O_2$

is the equilibrium constant expression for the reaction _____.

a) $2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g)$
b) $H_2O(g) \rightleftharpoons H_2(g) + 1/2O_2(g)$
c) $H_2O(g) \rightleftharpoons 2H(g) + O(g)$
d) $2H_2O(g) \rightleftharpoons 2H_2(g) + O_2(g)$
e) $H_2 + O_2 \rightleftharpoons H_2O$

12. $4CuO(s) + \overset{1}{CH_4}(g) \rightleftharpoons \overset{1}{CO_2}(g) + 4Cu(s) + \overset{2}{2H_2O}(g)$ $\Delta n = 2$ (gases)

The value of K_c for this reaction is 1.10 at 25.0°C. What is the value of K_p for this reaction? (R = 0.0821 L-atm/K-mol)

a) 658
b) 37.2
c) 26.9
d) 4.63
e) 1.52×10^{-3}

$K_p = K_c (RT)^{\Delta n}$

$K_p = (1.10)(0.0821 \cdot 298)^2 = 658$

13. Consider the following reaction at equilibrium:

$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$ $\Delta H° = +92.4$ kJ

Adding $N_2(g)$ to the system at equilibrium will _____.

a) decrease the concentration of $NH_3(g)$ at equilibrium
b) decrease the concentration of $H_2(g)$ at equilibrium
c) increase the value of the equilibrium constant
d) cause the reaction to shift to the right
e) remove all of the $H_2(g)$

14. What is the conjugate acid of NH_3?

a) NH_3
b) NH_2^+
c) NH_3^+
d) NH_4^+
e) NH_4OH

Add an H^+

15. For which one of the following does $K_c = K_p$ at 25°C?

a) $H_2(g) + F_2(g) \rightleftharpoons 2HF(g)$
b) $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$
c) $Al_2(SO_3)_3(s) + 6HCl(g) \rightleftharpoons 2AlCl_3(s) + 3H_2O(l) + 3SO_2(g)$
d) $NH_4Br(s) + KOH(s) \rightleftharpoons NH_3(g) + KBr(s) + H_2O(l)$
e) $2HF(g) \rightleftharpoons H_2(g) + F_2(g)$

Both since $\Delta n = 0$ (either)

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16. A 3.25 L tank was found to contain 0.343 mol O_2, 0.0212 mol SO_3, and 0.00419 mol SO_2, when equilibrium was attained. The equilibrium constant for the reaction below is _____.

$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$

E 0.0212 0.00419 0.343 M

a) 6.78×10^{-2}
b) 1.34×10^{-2}
c) 4.12×10^{-3}
d) 4.35×10^{-2}
e) 8.78

$$K_c = \frac{[SO_2]^2[O_2]}{[SO_3]^3}$$

$$K_c = \frac{\left(\frac{0.00419}{3.25}\right)^2 \left[\frac{0.343}{3.25}\right]}{\left(\frac{0.0212}{3.25}\right)^2} = 0.00412$$

17. What is the pH of a 0.015 M solution of barium hydroxide?

a) 12.48
b) 12.18
c) 1.82
d) 10.35
e) 1.52

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

$[OH^-] = 0.030$ $\quad pOH = -\log 0.030 = 1.52$

18. The effect of a catalyst on an equilibrium is to _____.

a) increase the rate of the forward reaction only
b) increase the equilibrium constant so that products are favored
c) slow the reverse reaction only
d) increase the rate at which equilibrium is achieved without changing the composition of the equilibrium mixture
e) shift the equilibrium to the right

19. Which one of the following is the weakest acid?

a) HF ($K_a = 6.8 \times 10^{-4}$)
b) HClO ($K_a = 3.0 \times 10^{-8}$)
c) HNO_2 ($K_a = 4.5 \times 10^{-4}$)
d) HCN ($K_a = 4.9 \times 10^{-10}$)
e) Acetic acid ($K_a = 1.8 \times 10^{-5}$)

20. The $[H^+]$ and pH of a 0.021 M HNO_3 solution at 25°C are _____ M and _____, respectively

Strong acid

$[H^+] = [HNO_3]$

$pH = -\log [0.021]$

a) 4.8×10^{-13}, 12.32
b) 4.8×10^{-13}, -12.32
c) 0.021, +1.68
d) 0.021, -1.68
e) 4.8×10^{-6}, +5.32

21. What is the % ionization of hypochlorous acid (HClO) in a 0.015 M aqueous solution of HClO at 25°C? ($K_a = 3.0 \times 10^{-8}$)

a) 4.5×10^{-8}
b) 14
c) 2.1×10^{-5}
d) 0.14
e) 1.4×10^{-3}

	$HClO \rightleftharpoons$	H^+	+ ClO^-
I	0.015	0	0
C	$-x$	$+x$	$+x$
E	$0.015-x$	x	x

$$K_a = \frac{x^2}{0.015 - x}$$

$x = 2.12 \times 10^{-5}$

$$\%_{ion} = \frac{2.12 \times 10^{-5}}{0.015} \times 100$$

$\%_{ion} = 0.14\ \%$

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22. $C_6H_6(g) + 3H_2(g) \rightleftharpoons C_6H_{12}(g)$

When 1.00 mol C_6H_6 and 3.00 mol H_2 were placed in a 200.0 L container and allowed to reach equilibrium over a catalyst at an elevated temperature, the resulting mixture contained 0.137 mol C_6H_{12}. The equilibrium amount (mol) of H_2 is _____. The initial amount of C_6H_{12} was zero.

a) 0.137
b) 0.411
c) 0.0457
d) 2.59
e) 2.86

$C_6H_6 + 3H_2 \rightleftharpoons C_6H_{12}$

I, 1.00 mol, 3.00 mol, 0

C, $-x$, $-3x$, $+x$

E, $1.00-x$, $3.00-3x$, x

E $1.00 - 0.137$, $3 - 3(0.137)$, $x = 0.137$ mol

H_2 $3.00 - 3(0.137) = 2.59$ mol

23. Consider the following reaction at equilibrium:

$2CO_2(g) \rightleftharpoons 2CO(g) + O_2(g) \qquad \Delta H° = -514$ kJ

heat is product

2 moles(g) $\rightleftharpoons$ 3 moles gas

The yield of CO(g) in reaction can be maximized by carrying out the reaction _____.

a) at high temperature and high pressure
b) at high temperature and low pressure
c) at low temperature and low pressure
d) at low temperature and high pressure
e) in the presence of solid carbon

24. Of the following substances, an aqueous solution of _____ will form basic solutions.

NH_4Cl (Acidic) $Cu(NO_3)_2$ (Acidic) K_2CO_3 (Basic) NaF (Basic)

a) NH_4Cl, $Cu(NO_3)_2$
b) K_2CO_3, NH_4Cl
c) NaF only
d) NaF, K_2CO_3
e) NH_4Cl only

$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$

$F^- + H_2O \rightleftharpoons HF + OH^-$

25. The $[OH^-]$ and pH of a 0.0012 M $Ba(OH)_2$ (strong base) solution at 25°C are _____ M and _____, respectively.

a) 0.00060, -2.62
b) 0.0012, +2.92
c) 0.0024, +11.38
d) 0.0024, +2.62
e) 0.0012, -2.92

$[OH^-] = 2 \times 0.0012 = 0.0024$

$pOH = -\log 0.0024 = 2.62$

$pH = 11.38$

26. At a certain temperature, a flask at equilibrium contains 0.0114 M HCl, 0.0931 M Cl_2, and 0.0154 M H_2. What is the value of K_c for the equilibrium: $2HCl(g) \rightarrow Cl_2(g) + H_2(g)$?

a) 0.0909
b) 11.0
c) 1.63×10^{-5}
d) 6.25×10^4
e) 0.126

$2HCl(g) \rightarrow Cl_2(g) + H_2(g)$

E, 0.0114, 0.0931, 0.0154

$$K_c = \frac{[0.0931][0.0154]}{[0.0114]^2} = 11.0$$

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27. The equilibrium constant for reaction (1) below is 4.22×10^{-3}. The value of the equilibrium constant for reaction (2) is _____.

$3\,A + 2\,B \rightleftharpoons 2\,D + E$ (1)

$2\,D + E \rightleftharpoons 3\,A + 2\,B$ (2)

$\frac{1}{4.22 \times 10^{-3}}$

a) 5.78×10^{-2}
b) 4.22×10^{-3}
c) 1.78×10^{-5}
d) 237
e) The value of K_2 cannot be determined from the data given.

28. Calculate the pH of 0.0385 M hypochlorous acid. ($K_a = 3.0 \times 10^{-8}$)

a) 1.41
b) 8.94
c) 4.47
d) 7.52
e) -1.41

weak acid $HClO(aq) \rightleftharpoons H^+ + ClO^-$

	$HClO$	H^+	ClO^-
I	0.0358	0	0
C	$-x$	$+x$	$+x$
E	$0.0358 - x$	x	x

$3.0 \times 10^{-8} = \frac{x^2}{0.0358 - x}$

$x = [H^+] = 3.38 \times 10^{-5}$

$pH = -\log = 4.48$

29. A 0.12 M solution of a particular weak acid has pH = 2.49. What is the K_a of this acid?

a) 3.2×10^{-3}
b) 4.8×10^{-2}
c) 1.8×10^{-5}
d) 4.8×10^{-12}
e) 8.6×10^{-5}

$HX \rightleftharpoons H^+ + X^-$

	HX	H^+	X^-
I	0.12	0	0
C	$-x$	$+x$	$+x$
E	$0.12 - x$	x	x

$K_a = \frac{x^2}{0.12 - x}$

$x = 10^{-2.49} = 0.00324$

$K_a = \frac{(0.00324)^2}{0.12 - 0.00324} = 8.7 \times 10^{-5}$

30. Which of the following acids is <u>not</u> a strong acid?

a) H_2CO_3
b) H_2SO_4
c) HNO_3
d) $HClO_4$
e) HCl

31. Nitrosyl bromide decomposes according to the following equation:

$$2NOBr(g) \rightleftharpoons 2NO(g) + Br_2(g)$$

A sample of NOBr (0.64 mol) was placed in a <u>1.00 L</u> flask containing no NO or Br_2. At equilibrium the flask contained 0.46 mol of NOBr. How many moles of NO and Br2, respectively, are in the flask at equilibrium?

a) 0.18, 0.18
b) 0.46, 0.23
c) 0.18, 0.090
d) 0.18, 0.360
e) 0.46, 0.46

	$2NOBr$	$\rightleftharpoons$	$2NO$	$+$	Br_2
I.	[0.64]		0		0
C.	$-2x$		$+2x$		$+x$
E.	$0.64 - 2x$		$2x$		x

$0.64 - 2x = 0.46$

$x = 0.09$ $\quad 2x = 0.18$ $\quad x = 0.09$

32. Consider the following equilibrium:

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

From which of the following starting conditions would it be impossible for this equilibrium to be achieved?

a) 1.0 mol $SO_3(g)$ in a 1.0-L container.
b) 0.25 mol $SO_2(g)$, 0.50 mol $O_2(g)$, and 0.10 mol $SO_3(g)$ in a 1.0- L container
c) 0.25 mol $SO_2(g)$ and 0.25 mol $O_2(g)$ in a 1.0-L container
d) 0.50 mol $O_2(g)$ and 0.50 mol $SO_3(g)$ in a 1.0-L container
e) Equilibrium can be achieved from any of these starting conditions.

33. What is the concentration (in M) of hydroxide ions in a solution at 25°C with pH = 4.282?

a) 4.282
b) 9.718
c) 1.91×10^{-10}
d) 5.22×10^{-5}
e) 1.66×10^{4}

$pOH = 14 - pH = 9.718$

$[OH^-] = 10^{-9.718} =$