CHM 1410-001
Spring 2005
Test 2 (100 pts)

Name (Please Print) ______________ ________

Rate = $k[A]^x[B]^y$; $\ln [A]_t/[A]_o = -kt$; $\ln[A]_t = -kt + \ln[A]_o$; $t_{1/2} = 0.693/k$;

$1/[A]_t = kt + 1/[A]_o$; $k = A\exp(-E_a/RT)$ $\ln k = (-E_a/R)(1/T) + \ln A$;

$$\ln\frac{k1}{k2} = \frac{Ea}{R}\left(\frac{T1-T2}{T1T2}\right)$$ R = 8.31 J/mol.K; R = 0.082 L.atm/mole.K

Multiple Choice

1.(5) The Arrhenius equation is $k = A\ e^{-(Ea/RT)}$. The slope of a plot of ln k vs. 1/T is equal to

A. $-k$ B. k C. E_a D. $-E_a/R$ E. A

2.(5) Which is the correct equilibrium constant expression for the following reaction?
$Fe_2O_3(s) + 3H_2(g) \rightleftharpoons 2Fe(s) + 3H_2O(g)$

A. $K_c = [Fe_2O_3]\ [H_2]^3 / [Fe]^2[H_2O]^3$
B. $K_c = [H_2] / [H_2O]$
C. $K_c = [H_2O]^3 / [H_2]^3$
D. $K_c = [Fe]^2[H_2O]^3 / [Fe_2O_3]\ [H_2]^3$
E. $K_c = [Fe]\ [H_2O] / [Fe_2O_3]\ [H_2]$

3.(5) Consider the two gaseous equilibria
$SO_2(g) + (1/2)O_2(g) \rightleftharpoons SO_3(g)$ K_1
$SO_3(g) \rightleftharpoons SO_2(g) + 1/2O_2(g)$ K_2

The values of the equilibrium constants K_1 and K_2 are related by

A. $K_2 = K_1^2$ B. $K_2^2 = K_1$ C. $K_2 = 1/K_1^2$ D. $K_2 = 1/K_1$
E. none of these.

$[S_2] = 0.2$ $[H_2S] = 0.25$
$[H_2] = 1$

4.(5) On analysis, an equilibrium mixture for the reaction $2H_2S(g) \leftrightharpoons 2H_2(g) + S_2(g)$ was found to contain 1.0 mol H_2S, 4.0 mol H_2, and 0.80 mol S_2 in a 4.0 L vessel. Calculate the equilibrium constant, K_c, for this reaction. $K = \frac{(1)^2(.2)}{(0.25)^2}$

A. 1.6 B. 3.2 C. 12.8 D. 0.64 E. 0.8

5.(5) For the reaction A + B → C + D, the activation energy of the uncatalyzed reaction is 45 kJ/mol. If a catalyst is added to this reaction, what is a feasible activation energy for the catalyzed reaction?

A. 50 kJ/mol
B. 45 kJ/mol
C. 40 kJ/mol
D. 0 kJ/mol
E. Less than 0 kJ/mol

For the following questions consider the reaction below at equilibrium:

$$2NOBr(g) \leftrightharpoons 2NO(g) + Br_2(g), \quad \Delta H^\circ_{rxn} = 30 \text{ kJ/mol}$$

6.(3) Predict the direction of reaction if the container volume is increased.

A. To *products* or *to the right*
B. To *reactants* or *to the left*
C. No effect

7.(3) Predict the direction of reaction if some NO is removed.

A. To *products* or *to the right*
B. To *reactants* or *to the left*
C. No effect

8.(3) Predict the direction of reaction if some NOBr is added.

A. To *products* or *to the right*
B. To *reactants* or *to the left*
C. No effect

9.(3) Predict the direction of reaction if the temperature is decreased.

A. To *products* or *to the right*
B. To *reactants* or *to the left*
C. No effect

10.(3) Predict the direction of reaction if a catalyst is added to the system.

A. To *products* or *to the right*
B. To *reactants* or *to the left*
C. No effect

Problems

1.(12) The rate constant for the first-order decomposition of C_4H_8 at 500°C is $9.2 \times 10^{-3}\ s^{-1}$. How long will it take for 10.0% of a 0.100 M sample of C_4H_8 to decompose at 500°C?

10% of 0.100 M = 0.0100 M

C_4H_8 remaining = 0.100 - 0.0100 = 0.090 M

$$\ln([A]_t/[A]_0) = -kt$$

$$-\frac{\ln([A]_t/[A]_0)}{k} = t \quad ; \quad \frac{-\ln([C_4H_8]_t/[C_4H_8]_0)}{k} = t$$

$$t = -\frac{\ln(0.09/0.10)}{9.2 \times 10^{-3}\ s^{-1}} = \frac{-(-0.105)}{9.2 \times 10^{-3}\ s^{-1}} = 11.4\ sec.$$

2.(14) At 700 K, the reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ has the equilibrium constant $K_c = 4.3 \times 10^6$, and the following concentrations are present: $[SO_2] = 0.10$ M; $[SO_3] = 10$ M; $[O_2] = 0.10$ M.

Is the mixture at equilibrium? If not at equilibrium, in which direction (as the equation is written), *left to right* or *right to left*, will the reaction proceed to reach equilibrium? (Show work for credit).

$$Q_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{10^2}{(0.10)^2(0.10)} = 1.0 \times 10^5$$

$Q_c = 1.0 \times 10^5$, $K_c = 4.3 \times 10^6$

$Q_c < K_c$

So Reaction proceeds to products (left to right) until $Q = K$

3.(14) 1.25 moles of NOCl were placed in a 2.50 L reaction chamber at 427°C. After equilibrium was reached, 1.10 moles of NOCl remained. Calculate the equilibrium constant, K_c, for the reaction $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$.

$[NOCl]_0 = 0.500$ M

	$2NOCl \rightleftharpoons$	$2NO$ +	Cl_2
I	0.500	0	0
C	-0.06	+0.06	+0.03
E	0.44	0.06	0.03

$$K_c = \frac{[NO]^2[Cl_2]}{[NOCl]^2} = \frac{(0.06)^2(0.03)}{(0.44)^2}$$

$K_c = 5.58 \times 10^{-4}$

4.(20) For the reaction $SO_2(g) + NO_2(g) \leftrightharpoons SO_3(g) + NO(g)$, the equilibrium constant is 18.0 at 1,200°C. If 1.0 mole of SO_2 and 2.0 moles of NO_2 are placed in a 20. L container, what concentration of SO_3 will be present at equilibrium?

$[SO_2]_0 = \frac{1 \text{ mole}}{20 \text{ L}} = 0.05 \text{ M}$ $\quad [NO_2]_0 = \frac{2 \text{ moles}}{20 \text{ L}} = 0.10 \text{ M}$

	SO_2 +	NO_2 ⇄	SO_3 +	NO
I	0.05	0.10	0	0
C	−x	−x	+x	+x
E	0.05−x	0.10−x	x	x

$$K_c = 18 = \frac{[SO_3][NO]}{[SO_2][NO_2]} = \frac{(x)(x)}{(0.05-x)(0.10-x)}$$

$$18 = \frac{x^2}{5\times10^{-3} - 0.15x + x^2}$$

$$0.09 - 2.7x + 18x^2 = x^2$$

$$0.09 - 2.7x + 17x^2 = 0$$

$a = 17, \quad b = -2.7, \quad c = 0.09$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{2.7 \pm \sqrt{(2.7)^2 - 4(17)(0.09)}}{2(17)}$$

$$x = \frac{2.7 \pm \sqrt{7.29 - 6.12}}{34} = \frac{2.7 \pm 1.08}{34}$$

$\cancel{x = 0.11}$ or $x = 0.047$

gives negative SO_2 conc.

$x = 0.047\text{M} = [SO_3]$