Rate = \[ \frac{d[A]}{dt} \] = \(-k\) \[ A \] = \(-kt + \ln[A]_0\) = \(-kt + \ln[A]_0\); \[ A_0 = 0.693k \]

\[ \ln[A] = -kt + \ln[A]_0 \]

\[ k = \text{Aexp}(\frac{E_a}{RT}) \]

\[ \ln k = (\frac{E_a}{R})(\frac{1}{T}) + \ln A \]

\[ \frac{k_1}{k_2} = \frac{E_a}{R}\left(\frac{T \ldots T_2}{1/T_2}\right) \]

\[ R = 8.31 \text{J/mole.K} \]

\[ n = 0.062 \text{L atm/mole.K} \]

Multiple Choice

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

A. \(-k\) \quad B. \(k\) \quad C. \(E_a\) \quad D. \(-E_a/R\) \quad E. \(A\)

2. (5) Which is the correct equilibrium constant expression for the following reaction?

\( \text{Fe}_2\text{O}_3(s) + 3\text{H}_2(g) \rightleftharpoons 2\text{Fe}(s) + 3\text{H}_2\text{O}(g) \)

A. \( K_c = \frac{[\text{Fe}]^2[\text{H}_2\text{O}]^3}{[\text{H}_2]^3[\text{Fe}_2\text{O}_3]} \)
B. \( K_c = \frac{[\text{H}_2]^3[\text{Fe}_2\text{O}_3]}{[\text{Fe}]^2[\text{H}_2\text{O}]^3} \)
C. \( K_c = \frac{[\text{Fe}]^2[\text{H}_2\text{O}]^3}{[\text{Fe}_2\text{O}_3][\text{H}_2]^3} \)
D. \( K_c = \frac{[\text{Fe}]^2[\text{H}_2\text{O}]^3}{[\text{Fe}_2\text{O}_3][\text{H}_2]^3} \)
E. \( K_c = \frac{[\text{Fe}_2\text{O}_3][\text{H}_2]^3}{[\text{Fe}]^2[\text{H}_2\text{O}]^3} \)

3. (5) Consider the two gaseous equilibria:

\( \text{SO}_2(g) + 1/2\text{O}_2(g) \rightleftharpoons \text{SO}_3(g) \quad K_1 \)

\( \text{SO}_3(g) \rightleftharpoons \text{SO}_2(g) + 1/2\text{O}_2(g) \quad K_2 \)

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

A. \( K_2 = K_1^2 \) \quad B. \( K_2 = K_1 \) \quad C. \( K_2 = 1/K_1^2 \) \quad D. \( K_1 = 1/K_2 \) \quad E. none of these.
4.5 On analysis, an equilibrium mixture for the reaction $2H_2(g) \rightleftharpoons 2H_2(g) + S(g)$ was found to contain 1.0 mol H₂, 4.0 mol H₂, and 0.80 mol S₂ in a 4.0 L vessel. Calculate the equilibrium constant, $K_c$, for this reaction.

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

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

4.8 For the reaction $A + B \rightarrow C + D$, the activation energy of the unanalyzed reaction is 45 kJ/mol. If a catalyst is added to this reaction, what is a feasible activation energy for the catalyzed reaction?

A. 30 kJ/mol  B. 45 kJ/mol  C. 60 kJ/mol  D. 0 kJ/mol  E. Less than 0 kJ/mol

For the following questions consider the reaction below at equilibrium:

$$2NOBr(g) \rightleftharpoons 2NO(g) + Br_2(g), \Delta H_{\text{rxn}} = -30 \text{ kJ/mol}$$

6.3 Predict the direction of reaction if the container volume is increased.

A. To products at the right  B. To reactants at the left  C. No effect

7.3 Predict the direction of reaction if some NO is removed.

A. To products at the right  B. To reactants at the left  C. No effect

8.3 Predict the direction of reaction if some NOBr is added.

A. To products at the right  B. To reactants at the left  C. No effect

9.3 Predict the direction of reaction if the temperature is decreased.

A. To products at the right  B. To reactants at the left  C. No effect
10.3 (a) Predict the direction of reaction if a catalyst is added to the system.  
   a. To products as to the right  
   b. To reactants as to the left  
   c. No effect

Problems

1.12 The rate constant for the first-order decomposition of C_2H_4 at 500°C is 9.2 \times 10^{-7} \text{ s}^{-1}.
   How long will it take for 10.0% of a 0.100 M sample of C_2H_4 to decompose at 500°C?

\[
\begin{align*}
\text{Initial concentration of C}_2\text{H}_4 &= 0.100 \text{ M} \\
\text{Final concentration of C}_2\text{H}_4 &= 0.090 \text{ M} \\
\text{Rate constant} (k) &= 9.2 \times 10^{-7} \text{ s}^{-1}
\end{align*}
\]

\[
\ln \left( \frac{\text{Initial concentration}}{\text{Final concentration}} \right) = -kt
\]

\[
-\ln \left( \frac{0.100}{0.090} \right) = -kt
\]

\[
t = \frac{-\ln \left( \frac{0.100}{0.090} \right)}{9.2 \times 10^{-7} \text{ s}^{-1}} = \frac{-0.103}{9.2 \times 10^{-7} \text{ s}^{-1}} = 11.4 \text{ s}
\]
2.(14) At 700 K, the reaction: \( 2\text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{SO}_3(g) \) has the equilibrium constant \( K_c = 4.3 \times 10^6 \), and the following concentrations are present: \([\text{SO}_2] = 0.10 \text{ M}\); \([\text{SO}_3] = 1.0 \text{ M}\); \([\text{O}_2] = 3.10 \text{ M}\).

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).

\[
K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 \times [\text{O}_2]} = 1.0 \times 10^5
\]

\[
K_c = 1.0 \times 10^5, \quad K_c = 4.3 \times 10^6
\]

\[K_c < K_c \]

So, \( \text{reaction proceeds to products, left to right} \)

until \( \text{L} \)

3.(14) 1.25 moles of NOCl were placed in a 2.50 L reaction chamber at 423°C. After equilibrium was reached, 1.10 moles of NOCl remained. Calculate the equilibrium constant, \( K_c \), for the reaction: \( 2\text{NOCl}(g) \rightleftharpoons 2\text{NO}(g) + \text{Cl}_2(g) \).

\[
\begin{align*}
2\text{NOCl} & \rightleftharpoons 2\text{NO} + \text{Cl}_2 \\
L & 2.50 \quad 0 \quad 0 \\
C & 0.90 \quad 1.0 \quad 0.23 \\
E & 0.41 \quad 0.90 \quad 0.23
\end{align*}
\]

\[
K_c = \frac{[\text{NO}]^2 \times [\text{Cl}_2]}{[\text{NOCl}]^2} = \frac{(0.90)^2 \times (0.23)}{(0.23)^2}
\]

\[
K_c = 5.38 \times 10^{-4}
\]
4.20 For the reaction $\text{SO}_2(g) + \text{NO}_2(g) \rightleftharpoons \text{SO}_3(g) + \text{NO}(g)$, the equilibrium constant is 18.0 at 1,200°C. If 1.8 moles of $\text{SO}_2$ and 2.0 moles of $\text{NO}_2$ are placed in a 20.0 L container, what concentration of $\text{SO}_2$ will be present at equilibrium?

\[
\begin{align*}
\text{K}_c &= 18 = \frac{[\text{SO}_3][\text{NO}]}{[\text{SO}_2][\text{NO}_2]} = \frac{(x)(x)}{(0.05-x)(0.10-x)} \\
18 &= \frac{x^2}{5 \times 10^{-3} - 0.15x + x^2} \\
0.9 &= 2.7x + 18x^2 = 0.09 \\
\alpha &= 17, \ b = -2.7, \ c = 0.09
\end{align*}
\]

\[
x = -0.47 \pm \frac{2.7 \pm \sqrt{2.7^2 - 4 \times 0.09}}{2} = 3.7 \pm 1.08
\]

\[
x = 3.7 + 1.08
\]

\[
x = 0.47 \text{ or } x = 0.047
\]

\[
\text{SO}_2 \text{ at } \alpha = 0.047
\]

\[
x = 0.47 \Rightarrow [\text{SO}_3]
\]