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BCI SCIENCE

SCH 4U

Reaction Rates:
Rate Law Problems

1. Cyclopropane, C_3H_6, is a gas used as a general anesthetic. It undergoes a slow molecular rearrangement to propylene. At a certain temperature, the following data were obtained relating concentration and rate.

	Initial $[C_3H_6]$ in mol/L	Rate of Formation of Propylene (mol/(L•s))
1	0.050	2.95×10^{-5}
2	0.100	5.90×10^{-5}
3	0.150	8.85×10^{-5}

$\frac{\text{rate } 2}{\text{rate } 1} = \frac{[C_3H_6]_2^m}{[C_3H_6]_1^m}$

$\frac{5.90\times10^{-5}}{2.95\times10^{-5}} = \frac{0.100^m}{0.050^m}$

$2^1 = 2^m$

$m = 1$

(a) What is the rate law for the reaction?

$r = k[C_3H_6]^1$

(b) Determine the value for the rate constant.

3 $r = k[C_3H_6]^1$

8.85×10^{-5} mol/(L·s) $= k[0.150$ mol/L$]^1$

$k = 5.90\times10^{-4}\ s^{-1}$

2. The following data were collected for the reaction: $M + N \rightarrow P + Q$

	Initial [M] in mol/L	Initial [N] in mol/L	Rate of Disappearance of M (mol/(L•s))
1	0.010	0.010	2.5×10^{-3}
2	0.020	0.010	5.0×10^{-3}
3	0.020	0.030	4.5×10^{-2}

$\frac{\text{rate } 2}{\text{rate } 1} = \frac{[M]_2^m}{[M]_1^n}$

$\frac{5.0\times10^{-3}}{2.5\times10^{-3}} = \frac{0.02^m}{0.01^n}$

$2^1 = 2^m$

$\frac{\text{rate } 3}{\text{rate } 2} = \frac{[N]_3^n}{[N]_2^n}$

$\frac{4.5\times10^{-2}}{5.0\times10^{-3}} = \frac{0.03^n}{0.01^n}$

$3^2 = 3^n$

$n = 2$

(a) What is the rate law for the reaction?

$r = k[M]^1[N]^2$

(b) Determine the value for the rate constant.

$r = k[M]^1[N]^2$

1 2.5×10^{-3} mol/(L·s) $= k[0.010$ mol/L$]^1[0.010$ mol/L$]^2$

$k = \frac{2.5\times10^{-3}\ \text{mol/(L·s)}}{1.0\times10^{-6}\ \text{mol}^3/\text{L}^3}$

$= 2{,}500\ s^{-1}\cdot mol^{-2}\ L^2$ $\frac{L^2}{mol^2\cdot s}$

$\frac{\cancel{mol}\cdot L^{\cancel{3}2}}{\cancel{L}\cdot s\ mol^{\cancel{3}2}}$

3. The reaction of iodide ion with hypochlorite ion, OCl^-, which is found in liquid bleach, follows the equation:

$$OCl^- + I^- \rightarrow O^- + Cl^-$$

It is a rapid reaction that gives the following rate data:

Initial [OCl^-] in mol/L	Initial [I^-] in mol/L	Rate of Formation of Cl^- (mol/L•s)
1 1.7×10^{-3}	1.7×10^{-3}	1.75×10^{4}
2 3.4×10^{-3}	1.7×10^{-3}	3.50×10^{4}
3 1.7×10^{-3}	3.4×10^{-3}	3.50×10^{4}

$\frac{rate\ 2}{rate\ 1} = \frac{[OCl^-]_2^m}{[OCl^-]_1^m}$

$\frac{3.50 \times 10^4}{1.75 \times 10^4} = \frac{3.4 \times 10^{-3}\ m}{1.7 \times 10^{-3}\ m}$

$2^1 = 2^m$

$m = 1$

$\frac{rate\ 3}{rate\ 1} = \frac{[I^-]_2^n}{[I^-]_1^n}$

$\frac{3.5 \times 10^4}{1.75 \times 10^4} = \frac{[3.4 \times 10^{-3}]}{[1.7 \times 10^{-3}]}$

$2 = 2^n$

$n = 1$

(a) What is the rate law for the reaction?

$r = k[OCl^-]^1[I^-]^1$

(b) Determine the value for the rate constant.

$1.75 \times 10^4\ mol/L \cdot s = k[1.7 \times 10^{-3}\ mol/L][1.7 \times 10^{-3}]^1$

$k = \frac{1.75 \times 10^4\ mol/L \cdot s}{2.89 \times 10^{-6}\ mol^2/L^2}$

$= 6.06 \times 10^9\ s^{-1} \cdot mol^{-1} \cdot L$

4. The formation of small amounts of nitric oxide, NO, in automobile engines is the first step in the formation of smog. Nitric oxide is readily oxidized to nitrogen dioxide by the reaction:

$$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$$

The following data were collected in a study of the rate of this reaction.

Initial [NO] in mol/L	Initial [O_2] in mol/L	Rate of Formation of $NO_{2(g)}$ (mol/L•s)
1 0.0010	0.0010	7.10
2 0.0010	0.0040	28.4
3 0.0030	0.0040	255.6

$\frac{rate\ 3}{rate\ 2} = \frac{[NO]_3^m}{[NO]_2^m}$

$\frac{255.6}{28.4} = \frac{0.0030^m}{0.0010^m}$

$3^2 = 3^m$

$m = 2$

$\frac{rate\ 2}{rate\ 1} = \frac{[O_2]_2^n}{[O_2]_1^n}$

$\frac{28.4}{7.10} = \frac{0.0040^n}{0.0010^n}$

$4 = 4^n$

$n = 1$

(a) What is the rate law for the reaction?

$r = k[NO]^2[O_2]^1$

(b) Determine the value for the rate constant.

1 $7.10\ mol/(L \cdot s) = k(0.001\ mol/L)^2(0.001\ mol/L)$

$7.10\ mol/(L \cdot s) = k\ 0.000000001\ mol^3/L^3$

$k = 7.1 \times 10^9\ L^2\ mol^{-2}\ s^{-1}$