Practice : Determing The Rate Law

1. $NH_4NO_{2(aq)} \rightarrow N_{2(g)} + 2H_2O_{(\ell)}$

$3h = 180\ min = 10800\ s$

$t = 0 \quad c = 0.500\ mol/L$

$t = 3h \quad c = 0.432\ mol/L$

$$rate = \frac{\Delta c}{\Delta t} = \frac{0.432\ mol/L - 0.500\ mol/L}{3h - 0h}$$

$$= \frac{-0.068\ mol/L}{10800\ s}$$

$$= -6.30 \times 10^{-6}\ \frac{mol}{L \cdot s}$$

∴ the average rate of decomposition of NH_4NO_2 is $-6.30 \times 10^{-6}\ \frac{mol}{L \cdot s}$

2. $rate = k[H_2O_2]^m[I^-]^n[H^+]^p$

$$\frac{rate_2}{rate_1} = \frac{k[0.020]^m[0.010]^n[0.00050]^p}{k[0.010]^m[0.010]^n[0.00050]^p} = \frac{2.3 \times 10^{-6}}{1.15 \times 10^{-6}}$$

$$\left(\frac{0.020}{0.010}\right)^m = 2$$

$$2^m = 2$$

$$2^1 = 2$$

$$m = 1$$

$$rate = k[H_2O_2]^1[I^-]^1[H^+]^0$$

$$= k[H_2O_2]^1[I^-]$$

$$1.15 \times 10^{-6}\ \frac{mol}{L \cdot s} = k\left(0.010\ \frac{mol}{L}\right)\left(0.010\ \frac{mol}{L}\right)$$

$$k = 0.0115\ \frac{L}{mol \cdot s}$$

$$\frac{rate_3}{rate_1} = \frac{k[0.010]^m[0.020]^n[0.00050]^p}{k[0.010]^m[0.010]^n[0.00050]^p} = \frac{2.3 \times 10^{-6}}{1.15 \times 10^{-6}}$$

$$2^n = 2$$

$$2^1 = 2$$

$$n = 1$$

∴ the rate law is

$$rate = 0.0115\ \frac{L}{mol \cdot s}[H_2O_2][I^-]$$

$$\frac{rate_4}{rate_1} = \frac{k[0.010]^m[0.010]^n[0.00100]^p}{k[0.010]^m[0.010]^n[0.00050]^p} = \frac{1.15 \times 10^{-6}}{1.15 \times 10^{-6}}$$

$$2^p = 1$$

$$2^0 = 1$$

$$p = 0$$

3. rate $= k[NO]^m [H_2]^n$

$$\frac{\text{rate}_3}{\text{rate}_1} = \frac{k\,[6.4\times10^{-3}]^m\,[4.5\times10^{-3}]^n}{k\,[6.4\times10^{-3}]^m\,[2.2\times10^{-3}]^n} = \frac{5.1\times10^{-5}}{2.6\times10^{-5}}$$

$$2.045^n = 1.9615$$

$$2^n \doteq 2$$

$$n = 1$$

rate $= k[NO]^2[H_2]^1$

$$2.6\times10^{-5}\ \frac{\text{mol}}{\text{L}\cdot\text{s}} = k\,(6.4\times10^{-3}\ \tfrac{\text{mol}}{\text{L}})^2\,(2.2\times10^{-3}\ \text{mol/L})$$

$k = 289 \quad \frac{\text{L}^2}{\text{s}\,\text{mol}^2}$

$$\frac{\text{rate}_2}{\text{rate}_1} = \frac{k\,[12.8\times10^{-3}]^m\,[2.2\times10^{-3}]^n}{k\,[6.4\times10^{-3}]^m\,[2.2\times10^{-3}]^n} = \frac{1.0\times10^{-4}}{2.6\times10^{-5}}$$

$$2^m = 3.846$$

$$2^2 \doteq 4$$

$$m = 2$$

$$\frac{\text{mol}}{\text{L}\cdot\text{s}} \div \frac{\text{mol}^4}{\text{L}^4}\ \frac{\text{mol}^2}{\text{L}^2}$$

$$\frac{1}{\text{s}} \times \frac{\text{L}^3}{\text{mol}^3}$$

4. Experiment 3 $[A] = 1.0$

$[B] = 2.0$

5. Rate $= k[A]^2[B][C]$

Find k $\quad 0.40\ \frac{\text{mol}}{\text{L}\cdot\text{s}} = k\,(0.10\ \text{mol/L})^2\,(0.20\ \text{mol/L})\,(0.050\ \text{mol/L})$

$$0.40\ \frac{\text{mol}}{\text{L}\cdot\text{s}} = k\,\left(0.0001\ \frac{\text{mol}^4}{\text{L}^4}\right)$$

$$k = 4000\ \frac{\text{L}^3}{\text{mol}^3\,\text{s}}$$

$$= 4000\,\text{L}^3\text{mol}^{-3}\text{s}^{-1}$$

$$\frac{\text{mol}}{\text{L}\cdot\text{s}} \div \frac{\text{mol}^4}{\text{L}^4}$$

$$\frac{\text{mol}}{\text{L}\cdot\text{s}} \times \frac{\text{L}^4}{\text{mol}^4}$$

$\therefore$ rate $= 4000\,\text{L}^3\text{mol}^{-3}\text{s}^{-1}[A]^2[B][C]$

Experiment # 2

$$\text{rate} = 4000[A]^2[B][C]$$

$$[B] = \frac{\text{rate}}{4000[A]^2[C]}$$

$$= \frac{0.40 \text{ mol/L·s}}{\frac{4000 \text{ L}^3}{\text{mol}^3\text{s}} (0.10 \text{ mol/L})^2 (0.100 \text{ mol/L})}$$

$$= 0.10 \frac{\text{mol}}{\text{L}}$$

∴ In experiment #2 [B] is $0.10 \frac{\text{mol}}{\text{L}}$

Experiment # 3

$$[C] = \frac{\text{rate}}{4000[A]^2[B]}$$

$$= \frac{0.20 \frac{\text{mol}}{\text{L·s}}}{4000 \frac{\text{L}^3}{\text{mol}^3\text{s}} (0.20 \text{ mol/L})^2 (0.050 \text{ mol/L})}$$

$$= 0.025 \frac{\text{mol}}{\text{L}}$$

∴ In experiment #3 [C] is $0.025 \frac{\text{mol}}{\text{L}}$

Experiment # 4

$$[A] = \sqrt{\frac{\text{rate}}{4000[B][C]}}$$

$$= \sqrt{\frac{0.45 \text{ mol/L·s}}{4000 \frac{\text{L}^3}{\text{mol}^3\text{s}} (0.025 \text{ mol/L})(0.040 \text{ mol/L})}}$$

$$= \sqrt{0.1125}$$

$$= 0.34 \frac{\text{mol}}{\text{L}}$$

∴ In experiment #4 [A] is $0.34 \frac{\text{mol}}{\text{L}}$

Experiment # 5

$$\text{rate} = 4000 \frac{\text{L}^3}{\text{mol}^3\text{s}} (0.10 \text{ mol/L})^2 (0.010 \text{ mol/L})(0.150 \text{ mol/L})$$

$$= 0.060 \frac{\text{mol}}{\text{L·s}}$$

∴ In experiment #5 the rate is $0.060 \frac{\text{mol}}{\text{L·s}}$