Rate Laws

Differential rate laws express (reveal) the relationship between the concentration of reactants and the rate of the reaction.

The differential rate law is usually just called "the rate law."

Integrated rate laws express (reveal) the relationship between concentration of reactants and time

Writing a (differential) Rate Law

Problem - Write the rate law, determine the value of the rate constant, k, and the overall order for the following reaction:

$$2\ NO(g) + Cl_2(g) \rightarrow 2\ NOCl(g)$$

Experiment	[NO] (mol/L)	$[Cl_2]$ (mol/L)	Rate Mol/L·s
1	0.250	0.250	1.43×10^{-6}
2	0.500	0.250	5.72×10^{-6}
3	0.250	0.500	2.86×10^{-6}
4	0.500	0.500	11.4×10^{-6}

Writing a Rate Law

Part 1 – Determine the values for the exponents in the rate law: $R = k[NO]^x[Cl_2]^y$

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In experiment 1 and 2, $[Cl_2]$ is constant while [NO] doubles. The rate quadruples, so the reaction is second order with respect to [NO] $\therefore R = k[NO]^2[Cl_2]^y$

Writing a Rate Law

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In experiment 2 and 4, [NO] is constant while $[Cl_2]$ doubles. The rate doubles, so the reaction is first order with respect to $[Cl_2]$ $\therefore R = k[NO]^2[Cl_2]$

Writing a Rate Law

Part 2 – Determine the value for k, the rate constant, by using any set of experimental data:

$$R = k[NO]^2[Cl_2]$$

Experiment	[NO] (mol/L)	$[Cl_2]$ (mol/L)	Rate Mol/L·s
1	0.250	0.250	1.43×10^{-6}

$$1.43x10^{-6}\frac{mol}{L\cdot s} = k\left(0.250\frac{mol}{L}\right)^2\left(0.250\frac{mol}{L}\right)$$

$$k = \left(\frac{1.43x10^{-6}}{0.250^3}\right)\left(\frac{mol}{L\cdot s}\right)\left(\frac{L^3}{mol^3}\right) = 9.15x10^{-5}\frac{L^2}{mol^2\cdot s}$$

Writing a Rate Law

Part 3 – Determine the overall order for the reaction.

$$R = k[NO]^2[Cl_2]$$

$$2 + 1 = 3$$

$\therefore$ The reaction is 3rd order

Overall order is the sum of the exponents, or orders, of the reactants