AP CHEMISTRY

TOPIC 8: KINETICS, PART A, Day 100:

- Reaction Order
- Rates Laws

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1. The reaction

$$2\,A + B \rightarrow C$$

using the data below, determine the orders for all the reactants, the rate law, and the value of the rate constant.

Experiment	[A]	[B]	Initial Rate ($M\ sec^{-1}$)
1	0.40	0.20	5.5×10^{-3}
2	0.80	0.20	5.5×10^{-3}
3	0.40	0.40	2.2×10^{-2}

a) What is the rate law?

$$\text{Rate} = k\,[\,A\,]^m\,[\,B\,]^n$$

$$\frac{Rate_{Exp\ 2}}{Rate_{Exp\ 1}} = \frac{5.5\times10^{-3}}{5.5\times10^{-3}} = 1$$

$$\frac{Rate_{Exp\ 2}}{Rate_{Exp\ 1}} = \frac{k\,[\,0.80\ M\,]^m\,[\,0.20\ M\,]^n}{k\,[\,0.40\ M\,]^m\,[\,0.20\ M\,]^n} = 2^m \quad ; \quad \frac{[\,0.80\ M\,]^m}{[\,0.40\ M\,]^m} = 2^m \quad ; \quad 2^m = 1$$

$$\boldsymbol{m = 0}$$

$$\frac{Rate_{Exp\ 3}}{Rate_{Exp\ 1}} = \frac{2.2\times10^{-2}}{5.5\times10^{-3}} = 4$$

$$\frac{Rate_{Exp\ 3}}{Rate_{Exp\ 1}} = \frac{k\,[\,0.40\ M\,]^m\,[\,0.40\ M\,]^n}{k\,[\,0.40\ M\,]^m\,[\,0.20\ M\,]^n} = 4 \quad ; \quad \frac{[\,0.40\ M\,]^n}{[\,0.20\ M\,]^n} = 4 \quad ; \quad 2.0^n = 4$$

$$\boldsymbol{n = 2}$$

$$\text{Rate} = k\,[\,A\,]^0\,[\,B\,]^2, \quad \textbf{OR} \quad \text{Rate} = k\,[\,B\,]^2$$

b) What is the value of the rate constant?

$$\text{Rate} = k\,[\,B\,]^2$$

$$k = \frac{Rate}{[\,B\,]^2} = \frac{2.2\times10^{-2}\ M}{(\,0.40\ M\,)^2\,(\text{sec})} = 0.1375\ M^{-1}\ \text{sec}^{-1}$$

2. The reaction

$$2\ NO\ +\ Cl_2\ \rightarrow\ 2\ NOCl$$

using the data below, determine the orders for all the reactants, the rate law, and the value of the rate constant.

Experiment	[NO]	[Cl_2]	Initial Rate ($M\ sec^{-1}$)
1	0.10	0.10	0.18
2	0.10	0.20	0.36
3	0.20	0.20	1.44

a) What is the rate law?

$$\text{Rate} = k\,[\ NO\ ]^m\,[\ Cl_2\ ]^n$$

$$\frac{Rate_{Exp\ 2}}{Rate_{Exp\ 1}} = \frac{0.36}{0.18} = 2$$

$$\frac{Rate_{Exp\ 2}}{Rate_{Exp\ 1}} = \frac{k\,[\ 0.10\ M\ ]^m\,[\ 0.20\ M\ ]^n}{k\,[\ 0.10\ M\ ]^m\,[\ 0.10\ M\ ]^n} = 2 \quad ; \quad \frac{[\ 0.20\ M\ ]^n}{[\ 0.10\ M\ ]^n} = 2 \quad ; \quad 2^n = 2$$

$$\boldsymbol{n = 1}$$

$$\frac{Rate_{Exp\ 3}}{Rate_{Exp\ 2}} = \frac{1.44}{0.36} = 4$$

$$\frac{Rate_{Exp\ 3}}{Rate_{Exp\ 2}} = \frac{k\,[\ 0.20\ M\ ]^m\,[\ 0.20\ M\ ]^n}{k\,[\ 0.10\ M\ ]^m\,[\ 0.20\ M\ ]^n} = 4 \quad ; \quad \frac{[\ 0.20\ M\ ]^m}{[\ 0.10\ M\ ]^m} = 4 \quad ; \quad 2.0^n = 4$$

$$\boldsymbol{m = 2}$$

$\text{Rate} = k\,[\ NO\ ]^2\,[\ Cl_2\ ]$, note, you do not need to put a "one" as an exponent – it is implied

b) What is the value of the rate constant?

$$\text{Rate} = k\,[\ NO\ ]^2\,[\ Cl_2\ ]$$

$$k = \frac{Rate}{[\ NO\ ]^2[\ Cl_2\ ]} = \frac{1.44\ M}{(\ 0.20\ M)^2(\ 0.20\ M)(\text{sec})} = 180\ M^{-2}\ \text{sec}^{-1}$$

3. The reaction between bromate ions and bromide ions in acidic solution is given by the equation below:

$$BrO_3^{-1} + 5\,Br^{-1} + 6\,H^{+1} \rightarrow 3\,Br_2 + 3\,H_2O$$

using the data below, determine the orders for all three reactants, the rate law, and the value of the rate constant.

Experiment	[BrO_3^{-1}]	[Br^{-1}]	[H^{+1}]	Initial Rate ($M\,sec^{-1}$)
1	0.10	0.10	0.10	8.0×10^{-4}
2	0.20	0.10	0.10	1.6×10^{-3}
3	0.20	0.20	0.10	3.2×10^{-3}
4	0.10	0.10	0.20	3.2×10^{-3}

a) What is the rate law?

$$\text{Rate} = k\,[\,BrO_3^{-1}\,]^m\,[\,Br^{-1}\,]^n\,[\,H^{+1}\,]^p$$

$$\frac{Rate_{Exp\ 2}}{Rate_{Exp\ 1}} = \frac{1.6\times10^{-3}}{8.0\times10^{-4}} = 2$$

$$\frac{Rate_{Exp\ 2}}{Rate_{Exp\ 1}} = \frac{k\,[\,0.20\ M\,]^m\,[\,0.10\ M\,]^n\,[\,0.10\ M\,]^p}{k\,[\,0.10\ M\,]^m\,[\,0.10\ M\,]^n\,[\,0.10\ M\,]^p} = 2 \quad ; \quad \frac{[\,0.20\ M\,]^m}{[\,0.10\ M\,]^m} = 2 \quad ; \quad 2^m = 2$$

$$\boldsymbol{m = 1}$$

$$\frac{Rate_{Exp\ 3}}{Rate_{Exp\ 2}} = \frac{3.2\times10^{-3}}{1.6\times10^{-3}} = 2$$

$$\frac{Rate_{Exp\ 2}}{Rate_{Exp\ 1}} = \frac{k\,[\,0.20\ M\,]^m\,[\,0.20\ M\,]^n\,[\,0.10\ M\,]^p}{k\,[\,0.20\ M\,]^m\,[\,0.10\ M\,]^n\,[\,0.10\ M\,]^p} = 2 \quad ; \quad \frac{[\,0.20\ M\,]^n}{[\,0.10\ M\,]^n} = 2 \quad ; \quad 2^n = 2$$

$$\boldsymbol{n = 1}$$

$$\frac{Rate_{Exp\ 4}}{Rate_{Exp\ 1}} = \frac{3.2\times10^{-3}}{8.0\times10^{-4}} = 4$$

$$\frac{Rate_{Exp\ 4}}{Rate_{Exp\ 1}} = \frac{k\,[\,0.10\ M\,]^m\,[\,0.10\ M\,]^n\,[\,0.20\ M\,]^p}{k\,[\,0.10\ M\,]^m\,[\,0.10\ M\,]^n\,[\,0.10\ M\,]^p} = 4 \quad ; \quad \frac{[\,0.20\ M\,]^p}{[\,0.10\ M\,]^p} = 4 \quad ; \quad 2^n = 4$$

$$\boldsymbol{p = 2}$$

$$\text{Rate} = k\,[\,BrO_3^{-1}\,]\,[\,Br^{-1}\,]\,[\,H^{+1}\,]^2$$

b) What is the value of the rate constant?

$$\text{Rate} = k\,[\,BrO_3^{-1}\,]\,[\,Br^{-1}\,]\,[\,H^{+1}\,]^2$$

$$k = \frac{Rate}{[\,BrO_3^{-1}\,][\,Br^{-1}\,][\,H^{+1}\,]^2} = \frac{3.2\times10^{-3}\ M}{(\,0.10\ M)(\,0.10\ M)(\,0.20\ M)^2(\sec)} = 8\ M^{-3}\ \sec^{-1}$$