OpenStax: Determining a Rate Law from Initial Rates

Example 12.4

Over the past several years, the atmospheric ozone concentration over Antarctica has decreased during the winter.

$NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g)$

This reaction has been studied in the laboratory, and the following rate data were determined at 25 °C.

Trial	[NO] (mol/L)	[O_3] (mol/L)	Δ[NO2]/Δt (mol L−1 s−1)
1	1.00×10^{-6}	3.00×10^{-6}	6.60×10^{-5}
2	1.00×10^{-6}	6.00×10^{-6}	1.32×10^{-4}
3	1.00×10^{-6}	9.00×10^{-6}	1.98×10^{-4}
4	2.00×10^{-6}	9.00×10^{-6}	3.96×10^{-4}
5	3.00×10^{-6}	9.00×10^{-6}	5.94×10^{-4}

Determine the rate law and the rate constant for the reaction at 25 °C.

Rate = $k[NO][O_3]$
$k = 2.20 \times 10^{7}\ L\ mol^{-1}\ s^{-1}$

Acetaldehyde decomposes when heated to yield methane and carbon monoxide according to the equation:

$CH_3CHO(g) \longrightarrow CH_4(g) + CO(g)$

Determine the rate law and the rate constant for the reaction from the following experimental data:

Trial	[CH_3CHO] (mol/L)	Δ[CH_3CHO]/Δt (mol L^{-1} s^{-1})
1	1.75×10^{-3}	2.06×10^{-11}
2	3.50×10^{-3}	8.24×10^{-11}
3	7.00×10^{-3}	3.30×10^{-10}

Rate = $k[CH_3CHO]^2$
$k = 6.73 \times 10^{-6}\ L\ /mol^{-1}\ s^{-1}$

Example 12.5

Using the initial rates method and the experimental data, determine the rate law and the value of the rate constant for this reaction:

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

Trial	[NO] (mol/L)	[Cl_2] (mol/L)	Δ[NO]/Δt(mol L−1 s−1)
1	0.10	0.10	0.0030
2	0.10	0.15	0.0045
3	0.15	0.10	0.00675

Rate = $k[NO]^2[Cl_2]$
$k = 3.0\ mol^{-2}\ L^2 s^{-1}$

Use the provided initial rate data to derive the rate law for the reaction whose equation is:

$OCl^-(aq) + I^-(aq) \longrightarrow OI^-(aq) + Cl^-(aq)$

Trial	$[OCl^-]$ (mol/L)	$[I^-]$ (mol/L)	Initial Rate (mol/L/s)
1	0.0040	0.0020	0.00184
2	0.0020	0.0040	0.00092
3	0.0020	0.0020	0.00046

Determine the rate law expression and the value of the rate constant k with appropriate units for this reaction.

Rate = $k[OCl^-]^2[I^-]$
$k = 5.8 \times 10^4\ L^2\ mol^{-2}\ s^{-1}$

21. Alcohol is removed from the bloodstream by a series of metabolic reactions. The first reaction produces acetaldehyde; then other products are formed. The following data have been determined for the rate at which alcohol is removed from the blood of an average male, although individual rates can vary by 25–30%. Women metabolize alcohol a little more slowly than men:

$[C_2H_5OH]$ (M)	4.4×10^{-2}	3.3×10^{-2}	2.2×10^{-2}
Rate (mol/L/h)	2.0×10^{-2}	2.0×10^{-2}	2.0×10^{-2}

Determine the rate equation, the rate constant, and the overall order for this reaction.

Rate = k
$k = 2.0 \times 10^{-2}\ mol\ L^{-1}\ h^{-1}$
Overall order = 0

22. Under certain conditions the decomposition of ammonia on a metal surface gives the following data:

[NH3] (M)	1.0×10^{-3}	2.0×10^{-3}	3.0×10^{-3}
Rate (mol/L/h)	1.5×10^{-6}	1.5×10^{-6}	1.5×10^{-6}

Determine the rate equation, the rate constant, and the overall order for this reaction.

Rate = k
$k = 1.5 \times 10^{-6}\ mol\ L^{-1}\ h^{-1}$
Overall order = 0

24. From the following data, determine the rate equation, the rate constant, and the order with respect to A for the reaction A ⟶ 2C.

[A] (M)	1.33×10^{-2}	2.66×10^{-2}	3.99×10^{-2}
Rate (mol/L/h)	3.80×10^{-7}	1.52×10^{-6}	3.42×10^{-6}

Rate = $k[A]^2$
$k = 2.15 \times 10^{-3}\ L^2\ mol^{-2}\ h^{-1}$
Order with respect to A = 2

25. Nitrogen monoxide reacts with chlorine according to the equation:

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

The following initial rates of reaction have been observed for certain reactant concentrations:

[NO] (mol/L)	[Cl_2] (mol/L)	Rate (mol/L/h)
0.50	0.50	1.14
1.00	0.50	4.56
1.00	1.00	9.12

What is the rate equation that describes the rate's dependence on the concentrations of NO and Cl_2?

What is the rate constant? What are the orders with respect to each reactant?

Answer: rate = $k[NO]^2[Cl_2]$
$k = 9.12\ L^3\ mol^{-3}\ h^{-1}$
Order with respect to NO = 2
Order with respect to Cl_2 = 1

26. Hydrogen reacts with nitrogen monoxide to form dinitrogen monoxide (laughing gas) according to the equation:

$H_2(g) + 2NO(g) \longrightarrow N_2O(g) + H_2O(g)$

Determine the rate equation, the rate constant, and the orders with respect to each reactant from the following data:

[NO] (M)	0.30	0.60	0.60
[H_2] (M)	0.35	0.35	0.70
Rate (mol/L/s)	2.835×10^{-3}	1.134×10^{-2}	2.268×10^{-2}

Rate = $k[NO]^2[H_2]$
$k = 9 \times 10^{-2}\ L^3\ mol^{-3}\ s^{-1}$
Order with respect to NO = 2
Order with respect to H_2 = 1

27. For the reaction A ⟶ B + C, the following data were obtained at 30 °C:

[A] (M)	0.230	0.356	0.557
Rate (mol/L/s)	4.17×10^{-4}	9.99×10^{-4}	2.44×10^{-3}

(a) What is the order of the reaction with respect to [A], and what is the rate equation?

Order with respect to A = 2
Rate = $k[A]^2$

(b) What is the rate constant?

$k = 7.88 \times 10^{-3}\ L^2\ mol^{-2}\ s^{-1}$

28. For the reaction Q ⟶ W + X, the following data were obtained at 30 °C:

$[Q]_{initial}$ (M)	0.170	0.212	0.357
Rate (mol/L/s)	6.68×10^{-3}	1.04×10^{-2}	2.94×10^{-2}

(a) What is the order of the reaction with respect to [Q], and what is the rate equation?

Order with respect to Q = 2
Rate = $k[Q]^2$

(b) What is the rate constant?

$k = 0.231\ L^2\ mol^{-2}\ s^{-1}$

31. The following data have been determined for the reaction:

$I^- + OCl^- \longrightarrow IO^- + Cl^-$

	1	2	3
$[I^-]$ initial (M)	0.10	0.20	0.30
$[OCl^-]$ initial (M)	0.050	0.050	0.010
Rate (mol/L/s)	3.05×10^{-4}	6.20×10^{-4}	1.83×10^{-4}

Determine the rate equation and the rate constant for this reaction

Rate = $k[I^-][OCl^-]$
$k = 6.1 \times 10^{-2}\ L^2\ mol^{-2}\ s^{-1}$

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