Rate Law Problems: Method of Initial Rates (LT 14e)

1. Given the below initial rate data for the following reaction:

$$2MnO_4^- + 5ClO_3^- + 6H^+ \rightarrow 2Mn^{2+} + 5ClO_4^- + 3H_2O$$

Exp. #	$[MnO_4^-]$	$[ClO_3^-]$	$[H^+]$	Initial Rate (M / s)
1	0.10 M	0.10 M	0.10 M	5.2×10^{-3}
2	0.25 M	0.10 M	0.10 M	3.3×10^{-2}
3	0.10 M	0.30 M	0.10 M	1.6×10^{-2}
4	0.10 M	0.10 M	0.20 M	7.4×10^{-3}

A) Determine the rate law.

$Rate=k[MnO_4^-]^2[ClO_3^-][H^+]^{0.5}$

B) Determine the rate constant.

$$5.2x10^{-3} = k[0.10]^2[0.10][0.10]^{0.5}$$
$$k = 16$$

2. Use the initial rate data below for the following reaction: **$2Mg + O_2 \rightarrow 2MgO$**

Trial	Initial [Mg] (mol/L)	Initial $[O_2]$ (mol/L)	Measured Rate (mol/Ls)
1	0.10	0.10	$2.0x10^{-3}$
2	0.20	0.10	$4.0x10^{-3}$
3	0.10	0.20	$8.0x10^{-3}$

A) Determine the rate law.

$Rate=k[Mg][O_2]^2$

B) Determine the rate constant.

$$2.0x10^{-3} = k[0.10][0.10]^2$$
$$k = 2$$

C) Determine the overall reaction order.

1+2=3rd order overall

3. The rate law for the reaction $2\ NO + O_2 \rightarrow 2\ NO_2$ is rate= $k[NO]^2[O_2]$. At 25ºC, $k=7.1\ X\ 10^9\ L\ mol^{-2}s^{-1}$. What is the rate of reaction when [NO] = 0.0010 mol/L and $[O_2]$=0.034 mol/L?

$$Rate = 7.1x10^9[0.0010]^2[0.034]$$
$$Rate = 240\ M/s$$

4. The table presents data for the reaction: $\mathbf{2H_2(g) + 2NO(g) \rightarrow 2H_2O(g) + N_2(g)}$
The temperature of the reaction is constant.

	Initial Concentration (M)		Initial Rate
Exp.	[NO]	[H2]	$-\Delta[NO]/\Delta t$ (M/s)
1	0.60	0.10	1.8×10^{-3}
2	0.60	0.20	3.6×10^{-3}
3	0.10	0.60	3.0×10^{-4}
4	0.20	0.60	1.2×10^{-3}

A) Determine the rate law expression for the above reaction system.

$$\text{Rate} = k[NO]^2[H_2]$$
$$1.8x10^{-3} = k[0.60]^2[0.10]$$
$$\text{Rate} = 0.050[NO]^2[H_2]$$

B) Calculate the necessary [NO] to achieve a rate of 8.0×10^{-4} M/s when $[H_2] = 0.35$ M.

$$[NO] = \left(\left[\frac{\text{rate}}{k[H_2]}\right]\right)^{0.5}$$
$$[NO] = \sqrt{\frac{8.0x10^{-4}}{[0.050][0.35]}} = 0.21\,M$$

C) What is the initial rate of production of $N_2(g)$ in trial #3?

$$\frac{\Delta[NO]}{2\Delta t} = \frac{\Delta N_2}{\Delta t}$$
$$\frac{3.0x10^{-4}}{2} = 1.5x10^{-4}\,M/s$$

5. From the following initial rate data for the reaction, $\mathbf{A + B + C \rightarrow}$ **products**,

	Initial Concentration (M)			
Exp.	[A]	[B]	[C]	Initial Rate
1	0.0184 M	0.0225 M	0.0141 M	0.000145 M s^{-1}
2	0.0368 M	0.0225 M	0.0141 M	0.000205 M s^{-1}
3	0.0184 M	0.0384 M	0.0141 M	0.000145 M s^{-1}
4	0.0184 M	0.0225 M	0.0365 M	0.000375 M s^{-1}

A) Deduce the rate law.

$$\text{Rate}=k[A]^{0.5}[C]$$

B) Calculate the value of the rate constant.

$$0.000145 = k[0.0184]^{0.5}[0.0141]$$
$$k = 0.0758$$
$$\text{Rate} = 0.0758[A]^{0.5}[C]$$

C) Calculate the initial rate for $[A]_o = 0.0307$ M, $[B]_o = 0.0228$ M, $[C]_o = 0.0183$ M.

$$\text{Rate} = 0.0758[0.0307]^{0.5}[0.0183]$$
$$\text{Rate} = 2.43\text{x}10^{-4}\ \text{M/s}$$

6. The initial rate of the reaction:

$BrO_3^-(aq) + 5\ Br^-(aq) + 8\ H^+(aq)$ ----> $3\ Br_2(l) + H_2O(l)$

Has been measured at the reactant concentrations shown (in mol/L):

Experiment	$[BrO_3^-]$	$[Br^-]$	$[H^+]$	Initial rate (mol/Ls)
1	0.10	0.10	0.10	8.0×10^{-4}
2	0.20	0.10	0.10	1.6×10^{-3}
3	0.10	0.20	0.10	1.6×10^{-3}
4	0.10	0.10	0.20	3.2×10^{-3}

According to these results what would be the initial rate (in mol/Ls) if all three concentrations are:
$[BrO_3^-]=[Br^-]=[H^+]=0.20$ mol/L?

$$\text{Rate} = k[BrO_3^-][Br^-][H^+]^2$$
$$8.0\text{x}10^{-4} = k[0.10][0.10][0.10]^2$$
$$\text{Rate} = 8.0[BrO_3^-][Br^-][H^+]^2$$
$$\text{Rate} = 8.0[0.20][0.20][0.20]^2$$
$$\text{Rate} = 0.013\ \text{M/s}$$

7. The reaction of iodide ion with hypochlorite ion, OCl^- (which is found in liquid bleach), follows the equation: **$OCl^- + I^-$ ----> $OI^- + Cl^-$** It is a rapid reaction that gives the following rate data.

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

A)What is the rate law for the reaction?

$$\text{Rate} = k[OCl^-][I^-]$$

B)Determine the value of the rate constant.

$$1.75\text{x}10^4 = k[1.7\text{x}10^{-3}][1.7\text{x}10^{-3}]$$
$$k = 6.1\text{x}10^9$$
$$\text{Rate} = 6.1\text{x}10^9[OCl^-][I^-]$$