WKS
Rate Laws From Experimental Data

Name Answer Key
Date ____________

1. The following reaction is done in lab: $\mathbf{NH_4^+ (aq) + NO_2^- (aq) \longrightarrow N_2 (g) + 2\,H_2O (l)}$
Data from many experiments using varying concentrations of reactants are collected. Data is given below.

Run #	Initial $[NH_4^+]$ (M)	Initial $[NO_2^-]$ (M)	Initial Rate (M/s)
1	0.01 ×2	0.2	5.4×10^{-7} ×2
2	0.02 ×2	0.2	10.8×10^{-7} ×2
3	0.04	0.2	21.5×10^{-7}
4	0.2	0.02 ×2	10.8×10^{-7} ×2
5	0.2	0.04 ×1.5	21.6×10^{-7} ×1.5
6	0.2	0.06	32.4×10^{-7}

a) What is the order of the reaction with respect to NH_4^+? Explain how you determined this.
1st order. When $[NH_4^+]$ is doubled from run 1 to 2 and 2 to 3, while $[NO_2^-]$ is held constant, the rate also doubles. Since Rate = $[NH_4^+]^x$, $2 = 2^x$ and $x = 1$.

b) What is the order of the reaction with respect to NO_2^-? Explain how you determined this.
1st order. When $[NO_2^-]$ is doubled from run 4 to 5 and increased by 1.5× from 5 to 6, while $[NH_4^+]$ is held constant, the rate increases by the same factor . Since Rate = $[NO_2^-]^y$, $2 = 2^y$ or $1.5 = 1.5^y$ and $y = 1$.

c) Complete the Rate Law for the reaction: **Rate =** $\boldsymbol{k}$ $[NH_4^+]^1[NO_2^-]^1$ or Rate = $k[NH_4^+][NO_2^-]$

2. The following reaction is done in lab: $\mathbf{A + B \longrightarrow C}$
Data from many experiments using varying concentrations of reactants are collected. Data is given below.

Run #	Initial [A] (M)	Initial [B] (M)	Initial Rate (M/s)
1	0.1 ×2	0.1 ×2	4.0×10^{-5} ×4
2	0.2	0.1	16.0×10^{-5} ×1
3	0.1	0.2	4.0×10^{-5}

a) What is the order of the reaction with respect to A? Explain how you determined this.
2nd order. When [A] is doubled from run 1 to 2, while [B] is held constant, the rate quadruples. Since Rate = $[A]^x$, $4 = 2^x$ and $x = 2$.

b) What is the order of the reaction with respect to B? Explain how you determined this.
0 order. When [B] is doubled from run 1 to 3, while [A] is held constant, the rate stays the same (factor of 1). Since Rate = $[B]^y$, $1 = 2^y$ and $y = 0$.

c) Write the Rate Law for the reaction: Rate = $k[A]^2[B]^0$ or Rate = $k[A]^2$

d) What is the *overall* reaction order?
Overall the reaction is $x + y = 2 + 0 = 2^{nd}$ order.

e) Determine the value of the rate constant k.

Using run 1, $4.0\times10^{-5}\ \text{M/s} = k[0.1\ \text{M}]^2$

$$k = \frac{4.0\times10^{-5}\ \text{M/s}}{0.01\ \text{M}^2} = 4.0\times10^{-3}/\text{M}\cdot\text{s} = 4.0\times10^{-3}\ \text{M}^{-1}\text{s}^{-1}$$

3. A chemical reaction is expressed by the balanced equation **A + B $\longrightarrow$ C**
Use the data below to answer the following questions.

Run #	Initial [A] (M)	Initial [B] (M)	Initial Rate (M/min)
1	0.20	0.20	2.0×10^{-4}
2	0.20	0.40	8.0×10^{-4}
3	0.40	0.40	1.6×10^{-3}

×2 ×2 ×4 ×2

a) Determine the rate law for the reaction.
The rate doubles when [A] doubles from 2 to 3, so 1st order in A (x = 1)
The rate quadruples when [B] doubles from 1 to 2 so 2nd order in B (y = 2)

Rate = $k[A][B]^2$

b) What is the overall reaction order? Overall order = x + y = 1 + 2 = 3, 3rd order overall

c) Calculate the value of the rate constant *k*.

$$2.0\times10^{-4}\ \text{M/min} = k[0.20\ \text{M}]^2[0.20\ \text{M}] \Rightarrow k = \frac{2.0\times10^{-4}\ \text{M/min}}{(0.040\ \text{M}^2)(0.2\ \text{M})} = \boxed{2.5\times10^{-2}\ \text{M}^{-2}\text{min}^{-1}}$$

d) Determine the initial rate when [A] = [B] = 0.30 M

$$\text{Rate} = (2.5\times10^{-2}\ \text{M}^{-2}\text{min}^{-1})(0.30\ \text{M})^2(0.30\ \text{M}) = \boxed{6.8\times10^{-4}\ \text{M/min}}$$

4. The reaction, X + Y $\rightarrow$ Z, is known to have the following rate law: Rate = $k[X]^2[Y]$.

a) What is the effect on the rate if the concentration of Y is reduced by one-third?
Since the reaction is 1st order in Y, reducing [Y] by ⅓ will also reduce the rate by ⅓.

b) What is the effect on the rate if the concentration of X is doubled?
Since the reaction is 2nd order in X, doubling [X] will quadruple (2^2) the rate.

c) What is the effect on the rate if the concentration of X is cut in half and the concentration of Y is doubled?
Rate = $k[0.5]^2[2]$ = (.25)(2) = 0.5. The rate will be cut in ½.

d) What is the effect on the rate if a catalyst is added to the system?
The catalyst increases the rate (by affecting *k*).