Name:_____ Date:_____ Block:_____

Differential Rate Laws WS (Homework)

For each reaction, determine the following:

a. order of each reactant
b. rate law expression
c. overall order of reaction
d. value of rate constant with proper units

1. The reaction: **$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$** was studied at 10°C. The following results were obtained.

rate = $k[NO]^m[Cl_2]^n$

Experiment	$[NO]_0$ (mol/L)	$[Cl_2]_0$ (mol/L)	Initial Rate (mol/L · min)
1	0.10	0.10	0.18
2	0.10	0.20	0.36
3	0.20	0.20	1.45

a) $\frac{\text{Exp 3}}{\text{Exp 2}}$: $\frac{1.45\ M/min}{0.36\ M/min} = \frac{k(0.20)^m(0.20)^n}{k(0.10)^m(0.20)^n}$

$4 = 2^m$

$m = 2$

∴ 2nd order w/ respect to NO

$\frac{\text{Exp 2}}{\text{Exp 1}}$: $\frac{0.36\ M/min}{0.18\ M/min} = \frac{k(0.10)^1(0.20)^n}{k(0.10)^1(0.10)^n}$

$2 = 2^n$

$n = 1$

∴ 1st order w/ respect to Cl_2

b) rate = $k[NO]^2[Cl_2]^1$ c) 3rd order overall d) $0.18\ M/min = k(0.10)^2(0.10)^1$

$k = 180\ 1/M^2 \cdot min$

2. The reaction: **$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$** was studied at 24°C. The following results were obtained.

rate = $k[I^-]^m[S_2O_8^{2-}]^n$

Experiment	$[I^-]_0$ (mol/L)	$[S_2O_8^{2-}]_0$ (mol/L)	Initial Rate (mol/L · s)
1	0.080	0.040	12.5×10^{-6}
2	0.040	0.040	6.25×10^{-6}
3	0.080	0.020	6.25×10^{-6}
4	0.032	0.040	5.00×10^{-6}
5	0.060	0.030	7.00×10^{-6}

a) $\frac{\text{Exp 2}}{\text{Exp 1}}$: $\frac{6.25 \times 10^{-6}\ M/s}{12.5 \times 10^{-6}\ M/s} = \frac{k(0.040\ M)^m(0.040\ M)^n}{k(0.080\ M)^m(0.040\ M)^n}$

$\frac{1}{2} = \left(\frac{1}{2}\right)^m$

$m = 1$

∴ 1st order w/ respect to I^-

$\frac{\text{Exp 1}}{\text{Exp 3}}$: $\frac{12.5 \times 10^{-6}\ M/s}{6.25 \times 10^{-6}\ M/s} = \frac{k(0.080\ M)^1(0.040\ M)^n}{k(0.080\ M)^1(0.020\ M)^n}$

$2 = 2^n$

$n = 1$

∴ 1st order w/ respect to $S_2O_8^{2-}$

2b) rate $= k[I^-]^1[S_2O_8^{2-}]^1$

c) 2nd order overall

d) $12.5 \times 10^{-6}\ M/s = k\,(0.080\ M)^1(0.040\ M)^1$

$$k = 3.9 \times 10^{-3}\ \frac{1}{M \cdot s}$$

3. The following data were obtained for the gas-phase decomposition of dinitrogen pentoxide.

$2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$ rate = $k[N_2O_5]^m$

Trial	$[N_2O_5]_0$ (mol/L)	Initial Rate (mol/L · s)
1	0.0750	8.90×10^{-4}
2	0.190	2.26×10^{-3}
3	0.275	3.26×10^{-3}
4	0.410	4.85×10^{-3}

a) $\frac{EXP\,2}{EXP\,1}$: $\frac{2.26 \times 10^{-3}\ M/s}{8.90 \times 10^{-4}\ M/s} = \frac{k(0.190\ M)^m}{k(0.0750\ M)^m}$

$2.5 = 2.5^m$

$m = 1$

∴ 1st order w/ respect to N_2O_5

b) rate = $k[N_2O_5]^1$

c) 1st order overall

d) $8.90 \times 10^{-4}\ M/s = k(0.0750\ M)^1$

$k = 1.19 \times 10^{-2}\ \frac{1}{s}$

4. The reaction $I^-(aq) + OCl^-(aq) \rightarrow IO^-(aq) + Cl^-(aq)$ was studied, and the following data were obtained: rate = $k[I^-]^m[OCl^-]^n$

Experiment	$[I^-]_0$ (mol/L)	$[OCl^-]_0$ (mol/L)	Initial Rate (mol/L · s)
1	0.12	0.18	7.91×10^{-2}
2	0.060	0.18	3.96×10^{-2}
3	0.030	0.090	9.88×10^{-3}
4	0.24	0.090	7.91×10^{-2}

5. After determining the rate law and rate constant in Question #4, calculate the initial rate for an experiment where both I^- and OCl^- are initially present at 0.15 mol/L.

4a) $\frac{EXP\,1}{EXP\,2}$: $\frac{7.91 \times 10^{-2}\ M/s}{3.96 \times 10^{-2}\ M/s} = \frac{k(0.12\ M)^m(0.18\ M)^n}{k(0.060\ M)^m(0.18\ M)^n}$

$2 = 2^m$

$m = 1$

∴ 1st order w/ respect to I^-

$\frac{EXP\,2}{EXP\,3}$: $\frac{3.96 \times 10^{-2}\ M/s}{9.88 \times 10^{-3}\ M/s} = \frac{k(0.06\ M)^1(0.18\ M)^n}{k(0.03\ M)^1(0.09\ M)^n}$

$4 = 2(2^n)$

$2 = 2^n$

$n = 1$

∴ 1st order w/ respect to OCl^-

4b) rate $= k[I^-]^1[OCl^-]^1$

c) 2nd order overall

d) 7.91×10^{-2} M/s $= k(0.12\ M)^1(0.18\ M)^1$

$$k = 3.7 \frac{1}{M \cdot s}$$

5) rate $= k[I^-]^1[OCl^-]^1$

rate $= \left(3.7 \frac{1}{M \cdot s}\right)(0.15\ M)^1(0.15\ M)^1 =$ **0.083 M/s**