Unit 4, Lesson 05: Homework on Reaction Rate Laws

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5. From trials 1 and 3:

- when $[C_2H_4O]$ doubles, the reaction rate also doubles, so rate = k $[C_2H_4O]^1$

Solve for k:

k = rate/$[C_2H_4O]^1$

$= \dfrac{5.84 \times 10^{-7} \text{ mol/L/s}}{0.00285 \text{ mol/L}}$

$= 0.000205 \text{ s}^{-1}$

Rate law:

rate = 0.000205 $s^{-}1$ $[C_2H_4O]^1$

6. From trials 1 and 3:

- when $[H_2]$ quadruples, the reaction rate also quadruples, so rate = k $[H_2]^1$

From trials 1 and 2:

- when [ICl] doubles, reaction rate also doubles, so rate = k $[ICl]^1$

Solve for k:

k = rate / $[H_2]^1[ICl]^1$

$= \dfrac{0.0015 \text{ mol/L/s}}{0.20 \text{ mol/L} \times 0.050 \text{ mol/L}}$

= 0.15 L / (mol · s)

Rate law:

rate = 0.15 L / (mol · s) $[H_2]^1$ $[ICl]^1$

7. From trials 1 and 2:

- when $[SO_2Cl_2]$ doubles, the reaction rate also doubles, so rate = k $[SO_2Cl_2]^1$

Solve for k:

k = rate / $[SO_2Cl_2]^1$

$= \dfrac{3.3 \times 10^{-6} \text{ mol/L/s}}{0.150 \text{ mol/L}}$

$= 2.2 \times 10^{-5} \text{ s}^{1-}$

Rate law:

rate = 2.2×10^{-5} s^{1-} $[SO_2Cl_2]^1$

8. Rate = $k[A]^2[B][C]$

Solve for k:

k = rate / $[A]^2$ [B] [C]

$= \dfrac{0.40 \text{ mol/L/s}}{[0.10]^2 [0.20] [0.050]}$

$= 4.0 \times 10^3 \text{ s}^{1-} \text{ L}^3/(\text{mol}^3 \cdot \text{s})$

Initial Concentration (mol/L)			Initial Rate (mol/L·s)
[A]	[B]	[C]	
0.10	0.20	0.050	0.40
0.10	0.10	0.10	0.40
0.20	0.050	0.025	0.20
0.34	0.025	0.040	0.45
0.10	0.010	0.15	0.060

Rate = 4.0×10^3 $L^3/(mol^3 \cdot s)$ $[A]^2[B][C]$

Rearrange the rate equation to solve for the unknown rate or concentration.

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2. Reaction: $a\,A + b\,B \rightarrow c\,C + d\,D$

   The rate law expression must be determined experimentally. We can not write the rate law by inspection using the coefficients from the overall equation, because it is only the coefficients from the rate determining step of the reaction mechanism that can be used to write the rate law.

3. Rate = $k\,[A]^2\,[B]$

a) One of the easiest ways to determine the effect on rate of changing concentrations is to substitute numbers into the equation.

- if [A] = 4 mol/L and [B] = 4 mol/L, the relative rate is $k\,[4]^2\,[4] = 64$

- if [A] is decreased by a factor of 2, then [A] becomes 2 mol/L
- if [B] is increased by a factor of 4, then [B] becomes 16 mol/L
- use these new values in the rate equation and relative rate is $k\,[2]^2\,[16] = 64$, which means that the relative reaction rate stays the same

b) if both [A] and [B] are doubled, then [A] becomes 8 mol/L and [B] becomes 8 mol/L

- relative rate is $k\,[8]^2\,[8] = 512$, which means that the rate is 8x faster than it was at the original concentrations

4. Rate = $k[HCrO_4^-]\,[HSO_3^-]^2\,[H^+]$

a) the reaction is first order in $[HCrO_4^-]$, second order in $[HSO_3^-]$, and first order in $[H^+]$
b) the overall reaction order is 4th order
c) the units for the rate constant k are $L^3 / (mol^3 \cdot s)$

5. Reaction: $A + B \rightarrow C + D$

a) From trials 1 and 2:
   - when [A] doubles, the reaction rate also doubles, so rate = $k\,[A]^1$

   From trials 2 and 3:
   - when [B] triples, reaction rate increases 9x or 3^2, so rate = $k\,[B]^2$

   The general rate law equation is rate = $k\,[A]^1\,[B]^2$

b) **Solve for k:**

$$k = \text{rate} / [A]^1[B]^2$$

$$= \frac{0.0050\ mol/L/s}{0.020\ mol/L \times [0.020\ mol/L]^2}$$

$$= 6.3 \times 10^2\ L^2 / (mol^2 \cdot s)$$

Rate law:

rate = $6.3 \times 10^2\ L^2 / (mol^2 \cdot s)\ [A]^1\ [B]^2$

Questions from Handout:

2. The following table shows the variation in rate with the concentrations of the reactants for the process:

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

Initial Concentration		Initial Rate (mol/L·s)
[A]	[B]	
1.0	1.0	0.20
2.0	1.0	1.6
3.0	1.0	5.4
2.0	2.0	3.2
1.0	3.0	0.60

a) Find the relationship between rate and the concentration of A.
   From trials 1 and 2, as [A] doubles, rate increases by 8x or 2^3 so rate = k $[A]^3$

b) What is the relationship between rate and [B] ?
   From trials 2 and 4, as [B] doubles, rate increases by 2x or 2^1 so rate = k $[B]^1$

c) Calculate "k" and write the rate law expression for this process.
   $k = \text{rate} / [A]^3[B]^1$

   $$= \frac{0.20 \text{ mol/L/s}}{[1.0 \text{ mol/L}]^3 \times [1.0 \text{ mol/L}]}$$

   $= 0.20 \text{ L}^3 / (\text{mol}^3 \cdot \text{s})$ so, rate = $0.20 \text{ L}^3 / (\text{mol}^3 \cdot \text{s}) [A]^3[B]^1$

d) What **change** would be observed in the rate if the concentrations of both A and B were doubled?
   - if [A] was doubled, the reaction rate would increase by 8x
   - if [B] was doubled, the reaction rate would increase by 2x
   - overall, if both were doubled, the reaction rate would increase by 16x

e) Calculate the **relative reaction rate** when [A] is 4 and [B] is 5.
   rate = $0.20 \text{ L}^3 / (\text{mol}^3 \cdot \text{s}) [A]^3[B]^1$

   $= 0.20 \text{ L}^3 / (\text{mol}^3 \cdot \text{s}) \; [4 \text{ mol/L}]^3 \; [5 \text{ mol/L}]$

   $= 64 \text{ mol / L} \cdot \text{s}$

3. The following rate information is for the reaction: $NO_2 + CO \rightarrow NO + CO_2$

Initial Concentration		Initial Rate (mol/L·s)
NO_2	CO	
0.010	0.010	1.0
0.010	0.020	8.0
0.010	0.030	27.0
0.020	0.010	2.0
0.060	0.020	48.0

a) Write the rate law expression for this system.

- from trials 1 and 2, when [CO] doubles, rate increases by 8x so, rate = $k[CO]^3$
- from trials 1 and 4, when $[NO_2]$ doubles, rate increases by 2x so, rate = $k[NO_2]^1$
- rate = $k\,[CO]^3[NO_2]^1$

Solve for k:

$k = \text{rate} / [CO]^3[NO_2]^1$

$$= \frac{1.0 \text{ mol/L/s}}{[0.010 \text{ mol/L}]^3 \times [0.010 \text{ mol/L}]}$$

$= 1.0 \times 10^8\ L^3 / (mol^3 \cdot s)$ so, rate = $1.0 \times 10^8\ L^3 / (mol^3 \cdot s)\ [CO]^3[NO_2]^1$

b) What **change** would there be in the rate if:

i) $[NO_2]$ is doubled, then the rate will double
ii) [CO] is tripled, then the rate will increase by (3^3) or 27 x
iii) both $[NO_2]$ and [CO] are doubled, then the rate will increase by 16x
iv) both $[NO_2]$ and [CO] are halved, the rate will decrease by 1/16 or 0.0625 times
v) $[NO_2]$ is doubled and [CO] is halved, the rate will decrease by ¼ or 0.25x

c) What is the **relative reaction rate** when $[NO_2]$ is 0.040 and [CO] is 0.060 ?

rate = $1.0 \times 10^8\ L^3 / (mol^3 \cdot s)\ [CO]^3[NO_2]^1$

$= 1.0 \times 10^8\ L^3 / (mol^3 \cdot s)\ [0.060]^3[0.040]^1$

$= 864\ mol / L \cdot s$