Reaction Rates

• **Chemical Kinetics** is the branch of chemistry concerned with the rates of chemical reactions

• **Reaction Rate** is the change in concentration of a reactant or a product of a chemical reaction per unit time
Measuring Reaction Rates

- **volume**
- **mass**
- **colour**
- **pH**
- **electrical conductivity**
Calculating Average Reaction Rates

• **Average Reaction Rate** is the change in reactant or product concentration over a given time interval.

\[
\text{rate}_A = \frac{\text{concentration of } A \text{ at time } t_2 - \text{concentration of } A \text{ at time } t_1}{t_2 - t_1}
\]

\[
\text{rate}_A = \frac{\Delta[A]}{\Delta t}
\]

• The units for average reaction rate are mol/L•s
Calculating Average Reaction Rates

• The average rate of reaction can be calculated in two ways:

\[ \text{rate}_A = -\frac{\Delta [A]}{\Delta t} \]

How fast a reactant disappears

\[ \text{rate}_B = \frac{\Delta [B]}{\Delta t} \]

How fast a product appears
Consider the following reaction:

A $\rightarrow$ B

Calculate the average rate at which reactant A is consumed

Calculate the average rate at which product B is produced
Calculating Average Reaction Rate

\[ C_4H_9Cl_{(aq)} + H_2O_{(l)} \rightarrow C_4H_9OH_{(aq)} + HCl_{(aq)} \]

<table>
<thead>
<tr>
<th>Time, ( t(s) )</th>
<th>([C_4H_9Cl] ) (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.1000</td>
</tr>
<tr>
<td>50.0</td>
<td>0.0905</td>
</tr>
<tr>
<td>100.0</td>
<td>0.0820</td>
</tr>
<tr>
<td>150.0</td>
<td>0.0741</td>
</tr>
<tr>
<td>200.0</td>
<td>0.0671</td>
</tr>
<tr>
<td>300.0</td>
<td>0.0549</td>
</tr>
<tr>
<td>400.0</td>
<td>0.0448</td>
</tr>
<tr>
<td>500.0</td>
<td>0.0368</td>
</tr>
<tr>
<td>800.0</td>
<td>0.0200</td>
</tr>
<tr>
<td>10,000</td>
<td>0</td>
</tr>
</tbody>
</table>

- Calculate the average rate of disappearance of chlorobutane
  - a) between 0s and 50.0s
  - b) between 50.0s and 100.0s
Graphing Average Reaction Rate

- What patterns do you notice in the data table below?

\[ C_4H_9Cl(aq) + H_2O(l) \rightarrow C_4H_9OH(aq) + HCl(aq) \]

<table>
<thead>
<tr>
<th>Time, ( t(s) )</th>
<th>([C_4H_9Cl] \text{ (M)})</th>
<th>Average Rate ( (M/s) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.1000</td>
<td>( 1.9 \times 10^{-4} )</td>
</tr>
<tr>
<td>50.0</td>
<td>0.0905</td>
<td>( 1.7 \times 10^{-4} )</td>
</tr>
<tr>
<td>100.0</td>
<td>0.0820</td>
<td>( 1.6 \times 10^{-4} )</td>
</tr>
<tr>
<td>150.0</td>
<td>0.0741</td>
<td>( 1.4 \times 10^{-4} )</td>
</tr>
<tr>
<td>200.0</td>
<td>0.0671</td>
<td>( 1.22 \times 10^{-4} )</td>
</tr>
<tr>
<td>300.0</td>
<td>0.0549</td>
<td>( 1.01 \times 10^{-4} )</td>
</tr>
<tr>
<td>400.0</td>
<td>0.0448</td>
<td>( 0.80 \times 10^{-4} )</td>
</tr>
<tr>
<td>500.0</td>
<td>0.0368</td>
<td>( 0.560 \times 10^{-4} )</td>
</tr>
<tr>
<td>800.0</td>
<td>0.0200</td>
<td></td>
</tr>
<tr>
<td>10,000</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Graphing Average Reaction Rate

Concentration of $\text{C}_4\text{H}_9\text{Cl} (\text{M})$ vs. Time (sec)

Average reaction rate $= \frac{\Delta [\text{C}_4\text{H}_9\text{Cl}]_{(aq)}}{\Delta t}$

This is the average reaction rate for the time period between 300-400 sec.
The average reaction rate can be calculated from the **slope of the secant** on a concentration-time graph.

\[
\text{rate}_A = -\frac{\Delta[A]}{\Delta t} \quad \text{or} \quad -\frac{\Delta y \text{ (concentration)}}{\Delta x \text{ (time)}}
\]
Graphing Average Reaction Rate

- What chemical reaction does this graph show?
Instantaneous Rate of Reaction

- **Instantaneous reaction rate** is the rate of a chemical reaction at a single point in time.
- It can be calculated from the *slope of the tangent* on a concentration-time graph.
Stoichiometric Rate Relationships

• Consider the following reaction:

\[ 2\text{H}_2\text{O}_2(\text{l}) \rightarrow \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \]

• We can use the stoichiometry of the reaction to conclude that the rate of appearance of oxygen is equal to half of the rate of disappearance of hydrogen peroxide.
Stoichiometric Rate Relationships

We can use the stoichiometry of a chemical reaction to make predictions about reaction rate

In general:

\[
aA + bB \rightarrow cC + dD
\]

rate = \(-\frac{1}{a} \frac{\Delta [A]}{\Delta t}\) = \(-\frac{1}{b} \frac{\Delta [B]}{\Delta t}\) = \(\frac{1}{c} \frac{\Delta [C]}{\Delta t}\) = \(\frac{1}{d} \frac{\Delta [D]}{\Delta t}\)
Practice

• Dinitrogen pentoxide gas decomposes to produce nitrogen dioxide gas and oxygen gas. If the rate of appearance of NO$_2$(g) is $2.0 \times 10^{-2}$ mol/L·s at 90s.

a) Determine the rate of appearance of O$_2$(g) at the same point in time

b) Determine the rate of disappearance of N$_2$O$_5$(g) at the same point in time
HOMEWORK

Required Reading:
  p. 346-361
  (remember to supplement your notes!)

Questions:
  p. 350 #1
  p. 352 #1
  p. 356 #1-2
  p. 360 #1-3
  p. 361 #1-5

Your Tan Line is Showing

y = -2/3x + 6