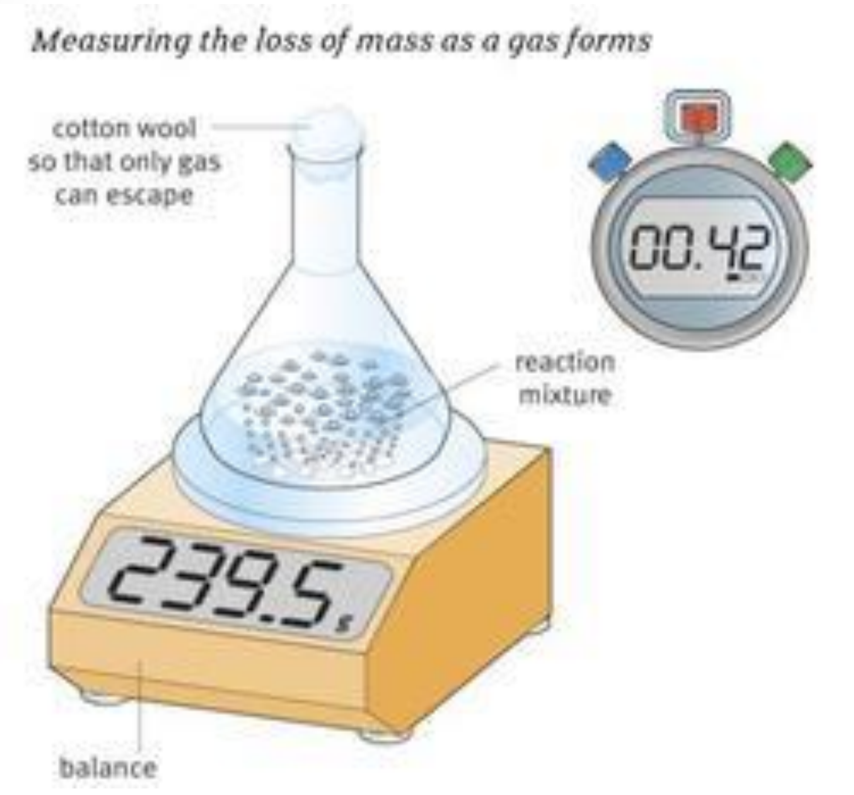
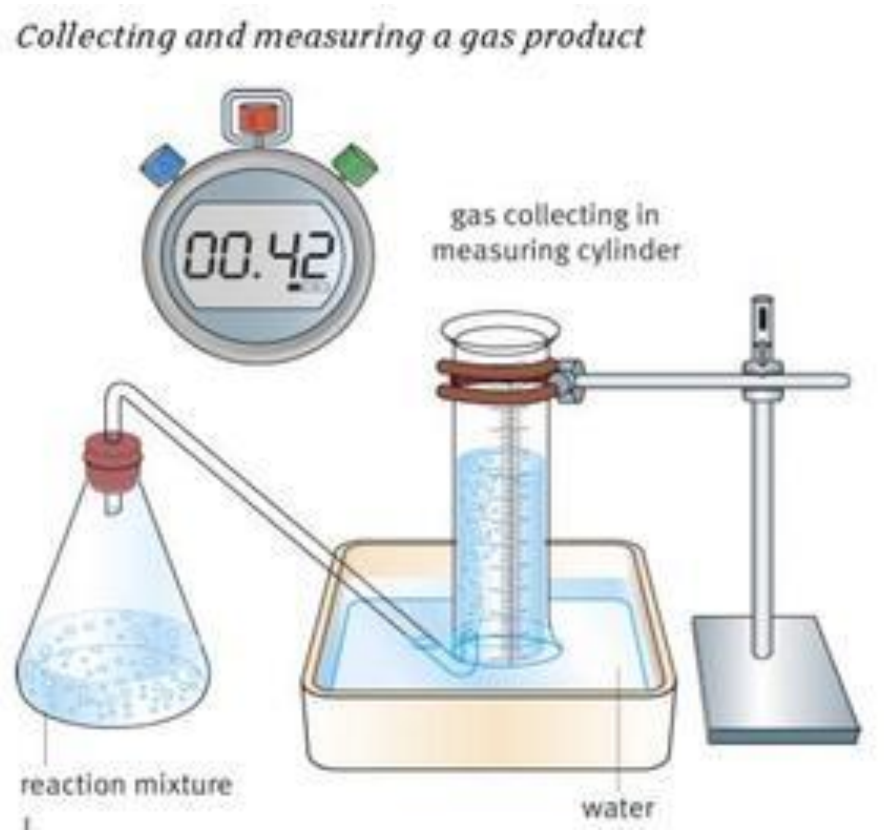
Measuring Reaction Rates





https://nkschemistry.wikispaces.com/Methods+of+measuring+rates+of+reaction

Outcomes:

- Formulate an operational definition of reaction rate.
- Identify variables used to monitor reaction rate.
- Perform a lab to measure average and instantaneous rates.

<u>Measuring Reaction Rates:</u>

<u>Recall:</u>

- The reaction rate is how **<u>QUICKLY</u>** a **<u>REACTANT</u>** is **<u>CONSUMED</u>**, or a **<u>PRODUCT</u>** is **<u>FORMED</u>**.

There are a number of **<u>VARIABLES</u>** we can use to **<u>DETERMINE</u>** the **<u>RATE</u>** of a reaction, depending on the **<u>TYPE</u>** of **<u>SUBSTANCES</u>** or **<u>REACTION</u>**:

1. ***Reactions that produce gas:***

- As **<u>GAS</u>** is **<u>PRODUCED</u>**, **<u>PRESSURE</u>** and **<u>VOLUME</u>** in the system will **<u>INCREASE</u>**.
- The **<u>FASTER</u>** the reaction, the more **<u>QUICKLY</u>** the **<u>CHANGE</u>** in **<u>VOLUME</u>** or **<u>PRESSURE</u>** will **<u>OCCUR</u>**.

Ex. $Zn_{(s)} + HCl_{(aq)} \rightarrow ZnCl_{(aq)} + H_{2(g)}$

→ Could use a pressure sensor, measure change in volume, or mass.

Measuring Reaction Rates:

2. ***Reactions involving ions:***

- When **IONS** are **PRODUCED**, the **CONDUCTIVITY** of a solution **INCREASES**.
- The more **QUICKLY** the **CONDUCTIVITY** changes, the **FASTER** the **REACTION**.
  - $(CH_3)_3CCl_{(aq)} + H_2O_{(l)} \rightarrow (CH_3)_3COH_{(aq)} + H^+_{(aq)} + Cl^-_{(aq)}$

    → Use a conductivity tester.

3. ***Reactions that change colour:***

- We can measure the **INTENSITY** of a **COLOUR** using a **SPECTROPHOTOMETER**.
- As a **COLOUR** is produced, its **INTENSITY** (**STRENGTH**) will **INCREASE**.
  - Ex. $ClO^-_{(aq)} + I^-_{(aq)} \rightarrow IO^-_{(aq)} + Cl^-_{(aq)}$
- The **YELLOW** colour of the **IO^-** becomes more and more **INTENSE** as the reaction **PROCEEDS**.

Measuring Reaction Rates:

4. ***Reactions involving acids/bases:***

- How quickly **pH** changes, will also indicate the **SPEED** of a reaction.
- For **NEUTRALIZATION** reactions, how quickly the **pH** returns to **7,** the **FASTER** the reaction.

As you can see, there are many factors that will indicate the rate of a reaction.

So, generally, rate is a change in some **VARIABLE** **X** over time **T**:

$$AverageRate = \frac{\Delta x}{\Delta t}$$

Calculating Average Rates:

We usually use the **CHANGES *in* CONCENTRATION** of **PRODUCTS** or **REACTANTS** over **TIME** to determine **RATE**.

$$a = \frac{\Delta v}{\Delta t} = \frac{\frac{m}{s}}{\frac{s}{1}} = \frac{m}{s} \times \frac{1}{s} = \frac{m}{s^2}$$

Recall: *Concentration = mol/volume = mol/L or M*

So we now have:

$$AverageRate = \frac{\Delta c}{\Delta t} = \frac{\frac{mol}{L}}{\frac{s}{1}} = \frac{mol}{L} \times \frac{1}{s} = \frac{mol}{L \cdot s}$$

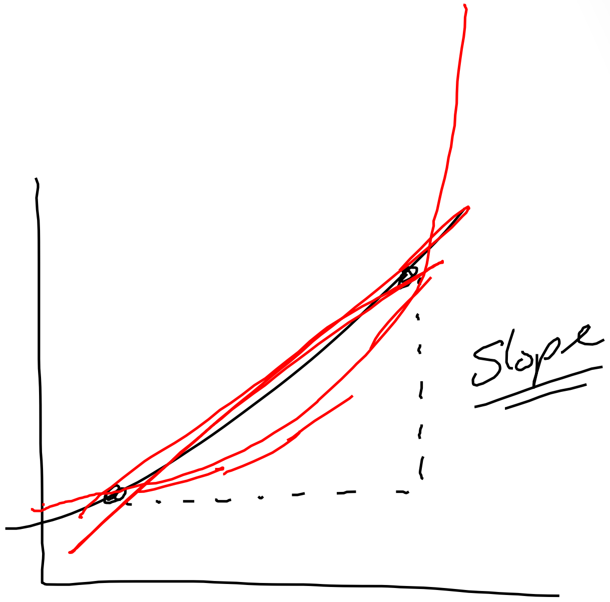
where rate is measured in $\frac{mol}{L \cdot s}$, or $mol \cdot L^{-1} \cdot s^{-1}$

$$x^{-2} = \frac{1}{x^2} \qquad x^{-1} = \frac{1}{x}$$

Calculating Average Rates:

Therefore…

$$AverageRate = \frac{\Delta c}{\Delta t} = \frac{[x_2]-[x_1]}{t_2 - t_1}$$



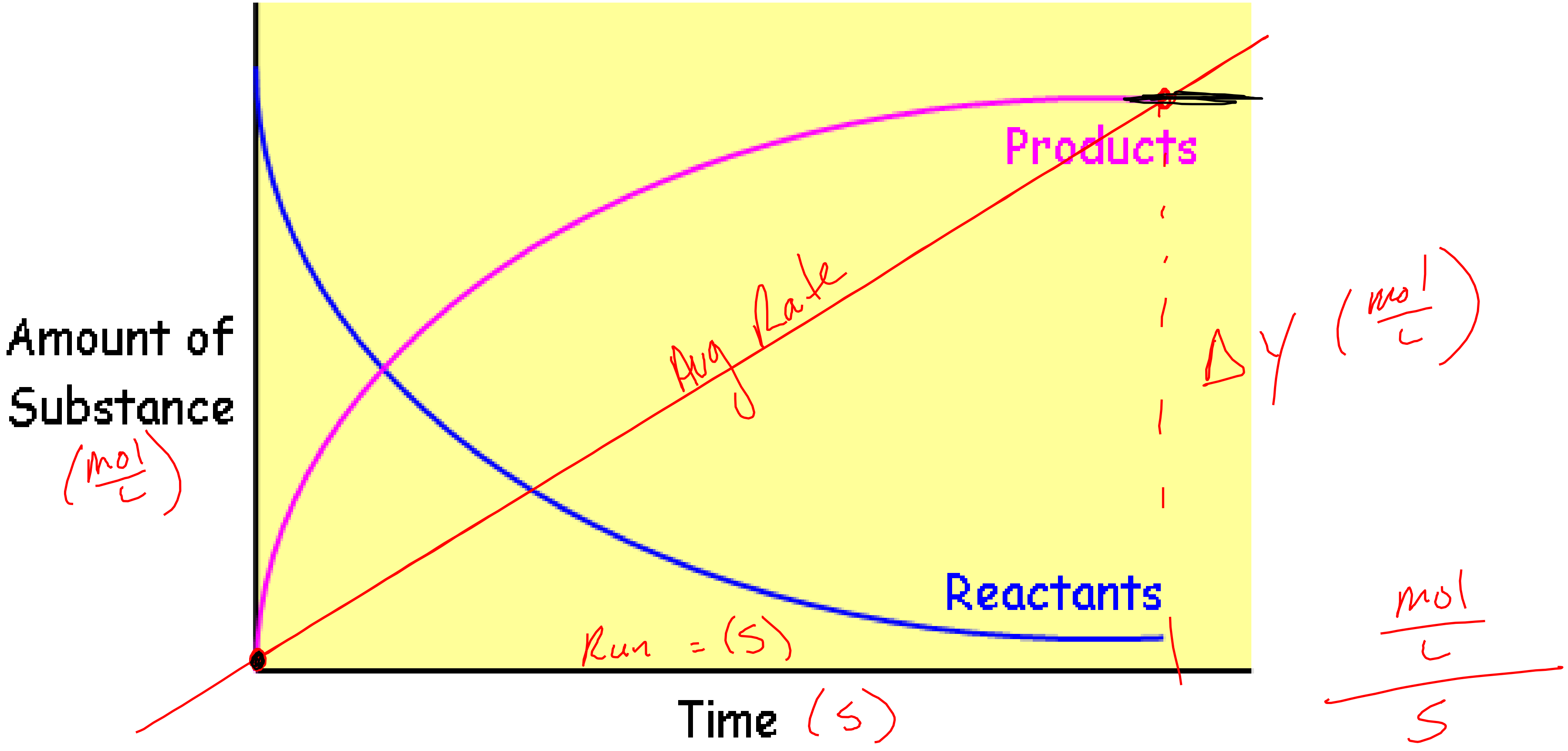
where: x_1 = the initial concentration

x_2 = the "final" concentration

Δt = the time elapsed

Rates & Graphs:

The **AVERAGE** rate of a reaction is simply the **SLOPE** of a **CONCENTRATION** vs. **TIME GRAPH**.



Note:

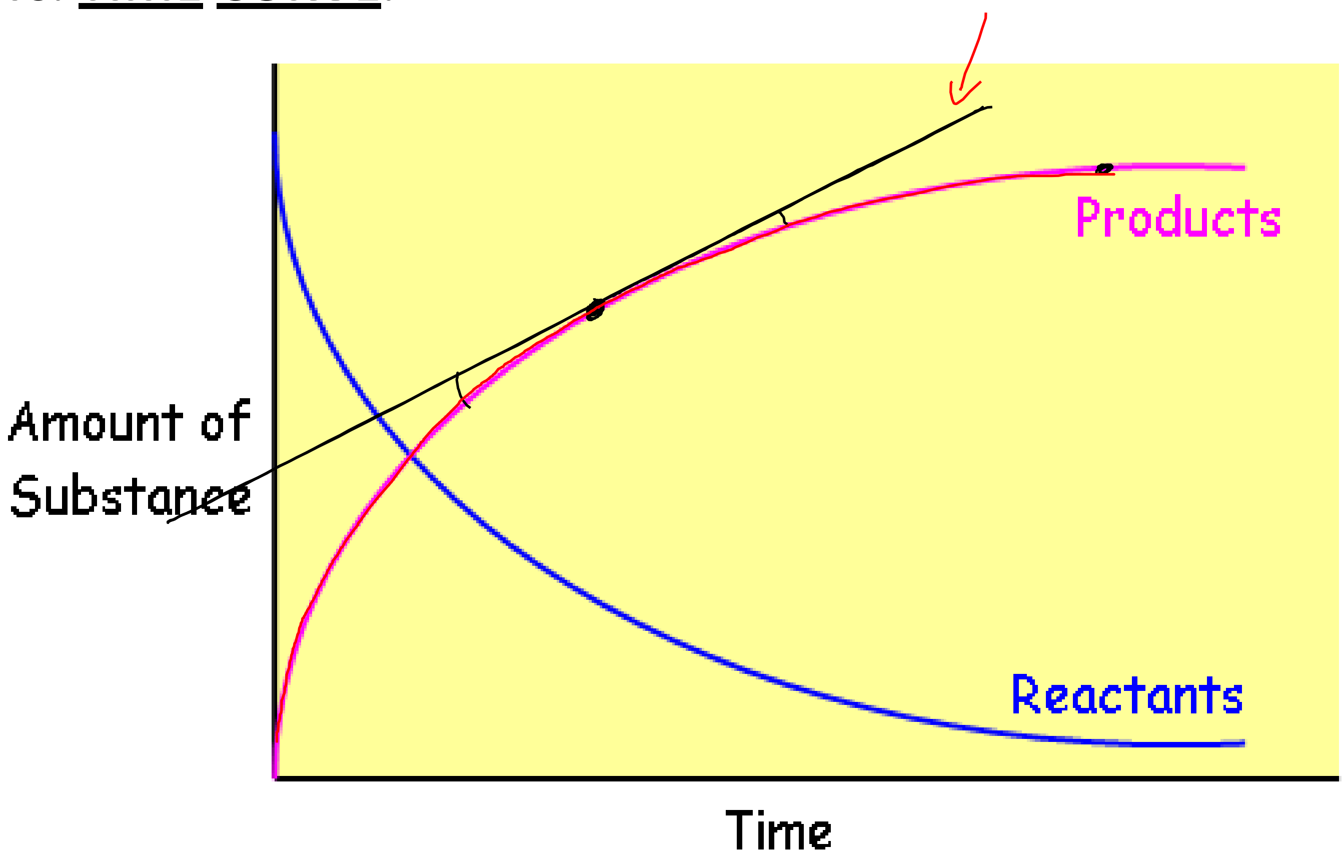
We cant have a **NEGATIVE** rate…they should always be **POSITIVE**!

$= \frac{mol}{L \cdot s}$

Rates & Graphs:

Instantaneous Rate

- Is the rate at a **SPECIFIC TIME**.
- This is determined by calculating the **SLOPE** of the **LINE TANGENT** to the **POINT** on the **CONCENTRATION** vs. **TIME CURVE**.



Calculating Average Rate:

Example 1:

Given the reaction A→ B, the following data was obtained:

Time (s)	Concentration of B (mol/L)
0.0	0.0
10.0	0.30
20.0	0.50
30.0	0.60
40.0	0.65
50.0	0.67

a) What is the average rate over the entire 50 seconds?

$$\text{Rate} = \frac{\Delta C}{\Delta t} = \frac{0.67\ \frac{mol}{L} - 0\ \frac{mol}{L}}{50\ s - 0\ s} = \frac{0.67\ \frac{mol}{L}}{50\ s} = 0.013\ \frac{mol}{L \cdot s}$$

b) What is the average rate for the interval 20 s to 40s?

$$= \frac{0.65\ \frac{mol}{L} - 0.5\ \frac{mol}{L}}{40\ s - 20\ s} = 0.0075\ \frac{mol}{L \cdot s}$$

Try this one:

The decomposition of nitrogen dioxide produces nitrogen monoxide and oxygen according to the reaction:

$$2\ NO_2(g) \rightarrow 2\ NO(g) + O_2(g)$$

Given the following data determine the rates below:

Time (s)	$[NO_2]$ (mol/L)	[NO] (mol/L)	$[O_2]$ (mol/L)
0	0.120	0.00	0.00
75	0.076	0.044	0.022
150	0.059	0.061	0.031
225	0.047	0.073	0.036
300	0.036	0.084	0.042

a) The average rate of decomposition of NO_2 over 300s.

$$Rate = \frac{\Delta [NO_2]}{\Delta t} = \frac{0.036\frac{mol}{L} - 0.120\frac{mol}{L}}{300s - 0s} = +2.8\times10^{-4}\ \frac{mol}{L\cdot s}$$

b) The average rate of production of NO over 300 s.

$$Rate = \frac{\Delta [NO]}{\Delta t} = \frac{0.084\frac{mol}{L} - 0}{300s} = 2.8\times10^{-4}\ \frac{mol}{L\cdot s}$$

c) The average rate of production of O_2 over 300 s.

$$Rate = \frac{\Delta [O_2]}{\Delta t} = \frac{0.042\frac{mol}{L}}{300s} = 0.00014\ \frac{mol}{L\cdot s} \quad (1.4\times10^{-4})$$