Appendix 3.1: Graphical Determination of Reaction Rate: Lab Activity

Introduction

The rate of a reaction can be calculated by studying the change in the amount of a product or a reactant at different times.

The **average rate of reaction** can be calculated using the following formula:

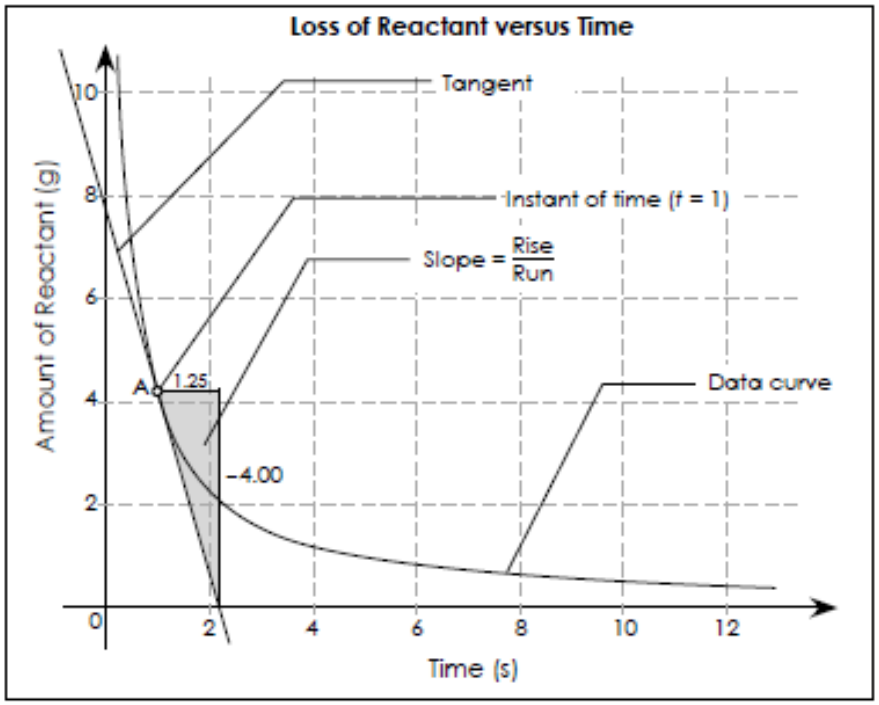
$$\text{Average rate} = \frac{\Delta \text{ amount of substance}}{\Delta \text{ time}}$$

Or

$$\text{Average rate} = \frac{\text{amount of substance at the end} - \text{amount of substance initially}}{\text{final time} - \text{initial time}}$$

This calculation, however, is only the average rate of reaction over a time period. It would be more useful to know the rate of the reaction at a specific time during the reaction. This rate, called the *instantaneous rate of reaction*, can be determined by measuring the amount of change in a product or a reactant at several times during a reaction. Using this data, a graph can be created and the instantaneous rate of reaction can be determined by drawing a tangent to the graph at any time and finding the slope of that tangent.

In reality, calculus is needed to find this slope, but an approximation can be determined by drawing a tangent line and finding the slope (as shown in the figure below). To do this, select two points on the tangent and calculate the slope using rise over run.



Purpose

In this lab activity, you will measure the loss of mass of a reactant at several times during a chemical reaction. Using the previous graph of the data, you will calculate the average and instantaneous rates of reaction.

The reaction involved is

$$2HCl_{(aq)} + CaCO_{3(s)} \longrightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

You will measure the loss of mass in this reaction as the carbon dioxide is released

Caution:
HCl is an acid. Gloves, goggles, and clothing protection must be worn.

Procedure

1. Place 10 to 12 large pieces of $CaCO_3$ into a paper cup or on filter paper on a scale. Pour 100 mL of 3.0 mol/L HCl solution into a 500 mL beaker. Place the beaker on the scale beside the $CaCO_3$. Record the total mass of everything.
2. With a stopwatch ready and the beaker on the scale, the person timing the lab activity should indicate when to pour the $CaCO_3$ chips into the acid and start the timer. Be sure to put the cup or filter paper back on the scale—it must remain there until the end of the experiment.
3. Record the mass every 30 seconds for 20 minutes.

Questions

1. The loss in mass in this reaction equals the amount of CO_2 produced. Calculate the mass of CO_2 produced for each 30-second time interval.
2. Calculate the average reaction rate. Using the average rate of reaction formula (provided at the start of this lab activity), determine the average rate of this reaction for the following time intervals:
   a) First 5 minutes
   b) First 10 minutes
   c) Last 5 minutes
   d) Last 10 minutes
   e) From 5 to 15 minutes
   f) For the entire 20 minutes
3. Construct a graph of mass of CO_2 produced versus time.

4. Calculate the instantaneous rate of reaction. On your graph, mark the point, draw an approximate tangent line, and calculate the slope of the tangent for the following instants of time:
   a) 30 seconds
   b) 60 seconds
   c) 5 minutes
   d) 10 minutes
   e) 15 minutes
   f) 20 minutes
5. What did you observe in the rate of this reaction from beginning to end? Why does the reaction rate change over time?
6. Explain when it would be useful to know the average rate of reaction and when you would need to know the instantaneous rate of reaction.