CHEMISTRY

0045 - Rate of Reaction

Lesson Objectives

- Investigate rate of reaction.
- Calculate rate of reaction and look at investigations that can determine rate of reaction.
- Investigate the factors that can affect the rate of reaction.
- Understand collision theory and the link between surface area and rate of reaction.

Course Notes

The rate of a reaction tells you how fast a chemical reaction occurs, i.e. how quickly the reactants turn into products. It can be determined by monitoring either how quickly the reactants are used up or by how quickly the products are made.

To calculate a 'mean rate of reaction' measure the rate of reaction in a given time and using one of the methods suggested below, calculate the quantity of reactant used divided by the time, or the quantity of product formed divided by the time.

Method 1:
One way to measure the rate of a reaction is to measure the decreasing mass of a reaction mixture, simply placing the mixture in a conical flask on a balance and recording the mass at fixed time intervals. The top of the conical flask should have a cotton wool bung to enable gas products to be released slowly, making it easier to measure and also preventing a build-up of pressure that might occur if a rubber bung was used.

Method 2:
An alternative way to measure the rate of a reaction when a gas is produced is to measure the volume of a gas produced, using a delivery tube attached to either a syringe or an upturned measuring cylinder over a trough of water. A syringe would be more accurate but if a large amount of gas is likely to be produced it would be safer to use an upturned measuring cylinder as the end of a syringe could be pushed off by the pressure of the gas. In this method of measuring the rate of reaction it is possible to measure how long it takes to produce a certain volume of gas, or measure the volume of gas produced at 10 second intervals.

Method 3:
Finally, if the reactants are solutions and one of the products is a solid, a technique called the disappearing cross can be used to measure when the solution had turned cloudy. A conical flask is placed on top of a thick black cross, the reagents are poured into the conical flask and the stopwatch started. As the reaction takes place more and more solid is made and gradually the black cross can no longer be seen through the solution. A more accurate way to measure this would be to use a light sensor linked to a data logger to continuously record the light intensity rather than rely on a subjective assessment of when the cross has actually disappeared by looking into the conical flask.

Any reaction relies on particles colliding with one another and having enough energy to react. This is known as 'collision theory'. As mentioned in the earlier episode on reaction profiles, there is a minimum amount of energy needed in order for particles to react, called the activation energy. Reactions are more likely to happen if you either increase how frequently the particles collide or if the energy of the particles is increased.

There are four factors that affect the rate of a reaction:

1. The surface area of any solid reactant. If the surface area is increased there will be a greater area for collisions to occur between the solid and the other reactant, making the reation happen faster. A strip of magnesium will burn brightly when it reacts with oxygen but sprinkling magnesium powder into a flame results in a rapid production of sparks because the reaction can occur more quickly.

2. The concentration of a liquid or the pressure of a gas. If you increase the concentration of a liquid, the particles are closer together and it is more likely that collisions will occur. The same is true if the pressure of a gas is increased, pushing the gas particles closer together. When reacting a piece of magnesium in acid, fizzing is seen as the hydrogen as is produced and the magnesium disappears as the magnesium chloride is made. This reaction is much faster in concentrated acid compared to dilute acid.

3. Use of a catalyst. The catalyst lowers the activation energy making it easier for particles to react if they collide. Catalysts only affect the rate of a reaction and do not take part in the reaction itself. As a result they can be re-used until eventually impurities build up and stop them working as effectively. The metals in used catalysts need to be disposed of carefully. By speeding up reactions, catalysts are useful in industry because they reduce the amount of energy needed and so reduce overall energy costs. On an energy level diagram, the effect of a catalyst would be shown as a smaller 'hump' for the activation energy.

4. Changing the temperature of the reactants. If the reactants are heated up they will have more energy, resulting in the particles moving about more creating more collisions and more successful collisions because more particles will enough energy to react when they do collide. The opposite is true if the reactants are cooled.

Often the rate of a reaction is plotted as a graph making it easy to see the effect of changing a particular variable on the rate over a period of time. In general, the steeper the slope of a graph, the faster the rate. When a reaction has finished the slope of the graph flattens out.

Higher Tier

In addition to a visual display, data can be obtained from the graph by drawing tangents. The initial rate of a reaction can be calculated by drawing a tangent at the start of a reaction (with the base of the tangent at zero). The gradient of the slope can be calculated by drawing a right-angled triangle and dividing the value of the opposite side of the triangle by the time. In a reaction where a gas is produced (cm^3) over a short amount of time measured in seconds, the units would be cm^3/s. The gradients can be compared for a reaction being carried out when one of the above four factors is varied.