How does temperature affect reaction rate?

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Introduction

Background concepts

In order for a chemical reaction to occur, the bonds in chemical reactants must break. According to collision theory, raising the temperature of a chemical reaction will result in more collisions between reactant particles thereby increasing the chances of successful collisions that result in the formation of new products. Sufficient energy, known as the activation energy, is required at the moment of impact to break existing bonds in reactants so that new bonds can be formed, resulting in reaction products.

Sodium thiosulfate reacts with hydrochloric acid to produce sulfur, sufur dioxide and water according to the equation:

$Na_2S_2O_3$ (aq) + 2HCl(aq) → S(s) + SO_2(g) + H_2O(l) + NaCl(aq)

The sulfur precipitate causes the reaction mixture to become cloudy. The rate at which the solution becomes cloudy indicates the rate of the reaction: the shorter the period before the cloudiness obscures a cross on a sheet of paper placed under the beaker, the more rapid the rate of a reaction.

Aim

In this experiment, the effect of temperature on the rate of the reaction is studied.

Hypothesis

If the temperature of the reaction between sodium thiosulfate and hydrochloric acid is increased, then the rate of the reaction will be increased and it will take a shorter time for the sulfur precipitate to form.

Methodology

The method for the investigation is based on the formation of a precipitate on completion of the chemical reaction between sodium thiosulfate and hydrochloric acid as an indicator that the reaction has been completed.

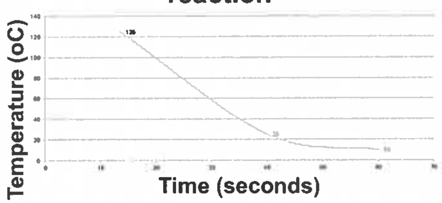
1. A cross was marked with a black pen on a sheet of white paper and placed under a 100 mL beaker.
2. 10 mL of 0.25 M sodium thiosulfate solution and 35 ml of distilled water were poured into the beaker, and the temperature of the solution was recorded.
3. 5 mL of 2.0 M hydrochloric acid solution was then added to the beaker and timing starting immediately to measure the time taken for the black cross to disappear when viewed from above the beaker.
4. Steps 2 and 3 were repeated, with the modification that the mixture in step 2 was heated to 40ºC using a heating block.
5. Steps 2 and 3 were repeated, with the modification that the mixture in step 2 was heated to 60ºC using a heating block.
6. The reaction time against temperature was recorded.

Safety and ethical considerations

1. Since sulfur dioxide can cause eye and respiratory irritation at high concentrations, and hydrochloric acid and sodium thiosulfate may cause skin or eye irritation, so safety glasses and a laboratory coat were worn. The experiment was performed in a fume cupboard and reaction mixtures were disposed via the sink in the fume cupboard.
2. Glassware can become hot with heating so tongs were used to avoid skin burns.

Results

Relationship between temperature and rate of reaction



Discussion

Analysis and evaluation of primary data

The graph of results shows that as the temperature increases the time that it takes for a cloudy precipitate of sulfur to form is shorter. There is an inverse relationship between temperature and time taken to form a precipitate, but it is unclear whether this is a linear relationship or not. The results appear to be linear in most part and then taper off, so further investigation is required. In addition, we need to be able to convert units of time taken for the precipitate to form into a rate – this is an inverse relationship itself, so that the relationship between increasing temperature and rate will be a direct one.

Data outliers

Since only three readings were taken in the experiment it is difficult to draw any conclusions about the mathematical relationship between temperature and the time taken for a precipitate to form. It could be that any of the three points could be 'outliers' in a curve or straight line. A further experiment is needed that involves taking more readings at varying temperatures between 30ºC and 80ºC to get a better idea of what is going on.

Limitations of data and methodologies

Only three readings were taken, as discussed in the section above, which limits the conclusions that can be drawn. The experiment was only performed once, so ideally it would have been better to repeat the experiment two more times to achieve greater reliability and validity of results.

Links between investigation results and concepts

The results show a direct relationship between temperature and rate of reaction. As the temperature of the reaction is raised, it takes a shorter time for the reaction products to be formed and hence the rate of the reaction increases. These results support the hypothesis of this experiment, and align with the collision theory. As the reactant particles gain more kinetic energy with increasing temperature, the number of collisions with each other increases. The increased collision rate means that the reactant particles have more chances to actually form successful collisions that result in the formation of products, including a visible precipitate. The formation of the precipitate is the basis of this experiment since it tells us when the change from reactants to products has occurred.

Conclusions

As the temperature for the reaction between sodium thiosulfate and hydrochloric acid is increased, it takes a shorter time for the sulfur precipitate product to form which corresponds to an increase in the rate of the reaction.

References and acknowledgements

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3. My logbook (12 April 2015/file location): raw data
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