Rate of Reaction Lab Analysis

1: Reaction Under Investigation

The reaction that we have chosen to investigate is the the neutralization reaction between powder Calcium Carbonate and aqueous Hydrochloric Acid. The reaction produces aqueous Calcium Chloride, liquid water and gaseous Carbon Dioxide.

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

2: Variables

2.1: Independent Variable

The independent variable of the experiment is temperature of the water which will be heated to the desired temperature using an electronic hot plate.

2.2: Dependent Variable

The dependent variable of the experiment is the rate of reaction of the neutralization reaction measured by the mass change method. The time taken to reduce each 0.01 second interval was recorded and the rate of reaction can be calculated as a mass change over time variable.

2.3: Controlled Variables

- *Quantity of Reactants:*

  The mass of reactants must be kept constant as an increase in the quantity of reactants will result in an increase in the total amount of products produced as well as the rate of reaction.

- *Surface Area of Reactants:*

The surface area of the reactants of the reactants must also be kept constant as increasing the surface area allows a greater quantity of atoms to react with at a given time which will also increase the rate of reaction.

- *Concentration:*

  The concentration of the hydrochloric acid was also kept constant as increasing the concentration also increases the number of molecules within a given volume. This effectively increased the quantity of reactants.

- *Stoichiometrically Matching Reactants:*

  Even though the reaction did not have to conclude to determine the initial rate of reaction, the hydrochloric acid and the calcium carbonate were matched stoichiometrically to ensure that there was no limiting reactant.

3: Experimental Method

The experimental method used to measure the rate of reaction of the neutralization reaction was mass change of the aqueous solution from the escaping carbon dioxide gas produced. The detailed experimental method is shown in a list below:

1. Mass of calcium carbonate and hydrochloric acid are measured in stoichiometrically matching proportions (1.0 g $CaCO_3$ + 15 ml HCl) and weighed using a paper weighing boat on an electronic balance and in a measuring cylinder.
2. The measured hydrochloric acid is poured into a beaker and heated to the desired temperatures (296K, 301K, 306K, 311K, 316K).
3. Place the hydrochloric acid on the electronic balance and zero the balance.
4. Add the calcium carbonate into the hydrochloric acid beaker and start a stopwatch timer.
5. Each time the mass of the balance decrease by 0.01g, measure the recorded time on the stopwatch.

6. When around 0.10g of carbon dioxide gas has been released, stop timing the reaction.
7. Repeat steps 1-6 for all temperature values.

4: Systematic Errors

4.1: Experimental Method

The experimental method chosen for the reaction was mass change from the carbon dioxide gas released. This method of rate of reaction measurement proved to be extremely inaccurate as the gas released had extremely low mass that could barely be measured accurately.

4.2: Surface Area

As the calcium carbonate is in the form of a powder, there were visible clumps that could alter the surface area of the reactants which could eventually increase or decrease the rate of the reaction.

4.3: Uneven Distribution of Temperature within Hydrochloric Acid

The temperature of the hydrochloric acid is measured using a digital thermometer which can only accurately measure the temperature of the aqueous solution surrounding the pointy part. However, the temperature of the solution will be intuitively higher closer to the hotplate rather than the at the surface, therefore an uneven distribution of temperature allows certain molecules of hydrochloric acid to have enough activation energy to react and others not enough. This will affect the overall rate of reaction as well.

4.4: Delay in Time Taken to Add Calcium Carbonate

As the calcium is weighed in a paper weighing boat and added to the hydrochloric acid, not all of the reactant are added at the same time. This will cause some of the calcium carbonate to start reacting while the others are still stuck on the paper weighing boat. This could shift the rate of reaction between trials.

5: Human Error

5.1: Reaction Time

The initial rate of the neutralization reaction is rather high and the mass changes on millisecond based intervals. This will lead to inaccurate measurements as the stopwatch is operated by a human experimenter who does not have an instant reaction time. This is extremely important for the first few intervals of mass change as small changes in delay will result in large slope changes when the rate of reaction is graphed.

6: Conclusion

To summarize, the experiment went rather poorly as there was many errors within both the procedure of the experiment as well as the human component. The experimental method chosen was unsuited for the quantity of reactants as the gas production did not result in significant mass changes. Due to the limited amount of reactants that was available to experiment with, a better method would have been to use the carbon dioxide censor, as it is better suited for reactions with small quantity of reactants. However, despite all of the errors, the collected data still indicated a conclusive result matching with the theoretical trend. As the temperature of the hydrochloric acid was increased, the rate of the neutralization reaction also increased, corresponding to the kinetic molecular theory.