Collated Questions – Reaction Rates

2014: 2 Balloons

(a) Calcium carbonate pieces are placed in a flask and hydrochloric acid is added. Immediately a balloon is placed over the top of the flask. The balloon then starts to inflate.

(i) Explain why the balloon inflates.
When a metal carbonate reacts with an acid, carbon dioxide gas is released. This gas causes the balloon to inflate.

In a second experiment, the same mass of calcium carbonate in a powdered form is used.

(ii) Explain why the balloon inflates faster when powdered calcium carbonate is used.
It is faster when powder is used, because the surface area of the powder is greater. Because there is more surface area, there is more surface (exposed calcium carbonate particles) with which the HCl particles can collide. Because more collisions occur more frequently, the rate is faster, and CO₂ will be generated more quickly.

(b) Using the same chemical substances (calcium carbonate and hydrochloric acid), discuss a different way to make the balloon inflate faster. In your answer you should refer to rates of reaction and particle collisions.

One way of making the reaction occur faster is to increase the concentration of the acid used. When this happens there are more HCl particles in the same volume of acid, and therefore there is a greater chance of collisions occurring more frequently, and so the rate of reaction is faster. Because the rate is faster, CO₂ is produced more rapidly, and the balloon inflates faster.

OR

The other way is to increase the temperature of the acid. When this happens, the HCl particles move faster; because they are moving faster, there is a greater chance of collisions occurring more frequently, and so the rate of reaction is faster. Because the rate is faster, CO₂ is produced more rapidly, and the balloon inflates faster.
2013: 3 REACTION RATES

The table below shows the size of marble chips (calcium carbonate) used in a chemical investigation into factors affecting rate of reaction.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Size of marble chips (calcium carbonate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1</td>
<td>small marble chips</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>large marble chips</td>
</tr>
</tbody>
</table>

The graph below shows the results for the volume of gas produced over a period of time.

(a) State what factor affecting the rate of reaction is being investigated in this experiment.
The factor being investigated is surface area of the calcium carbonate / marble chips.

(b) Explain what is happening in Experiment 1 in sections A, B, and C of the graph in terms of reaction rate. In your answer you should refer to particle collisions.
In section A of the graph the rate is fastest as there are more collisions between the HCl and CaCO₃. This is because at the start of the reaction there are more particles available for collision. In section B the rate of reaction is slowing down as the number of particles available for collision is becoming fewer as some of the HCl and CaCO₃ have already collided and have been used up, therefore fewer particles and therefore fewer collisions.
In part C the reaction has stopped, as all of the reactants (or one of them) have reacted, and therefore there are no particles present that can collide and react.
(c) Explain why Experiment 1 was faster than Experiment 2.
In your answer you should:
- explain how the graph shows that Experiment 1 is faster
- explain how the size of the marble chips affects the number of particle collisions.

The rate of Experiment 1 is faster as the slope in section A of the graph is steeper than in Experiment 2. It is faster because when smaller chips are used, the surface area of the chips is greater. Because there is more surface area, there is more surface for the HCl particles to collide. Because there are more collisions occurring more frequently, the rate is faster.

2012:4 REACTION RATES
The following experiment was carried out at 20°C and then repeated at 40°C. Marble chips (calcium carbonate) were added to hydrochloric acid in a conical flask. The mass and size of marble chips, and the concentration and volume of hydrochloric acid used, were the same for both experiments. The flask was connected to an inverted measuring cylinder in a basin of water, as shown in the diagram below.

The volume of gas produced at the two different temperatures was measured for a few minutes and the results were used to sketch the graph shown below.

State which line on the graph represents the reaction at 40°C and explain how you worked this out.
In your answer you should:
- identify which line represents the reaction at 40°C
- explain why the line you have identified is the reaction at 40°C
- give reasons for the different rates of reaction in terms of particles
- explain why both lines end up horizontal.
The reaction is faster at the higher temperature, because the H+ ions have more kinetic energy, and therefore are moving faster. When they are moving faster, there will be more collisions, and more of these collisions will be effective, as the particles will collide with more energy. Line B represents the faster reaction, as it is steeper at the start. This represents the reaction carried out at 40°C. Both lines become horizontal at the same point on the Y-axis, as this is when both reactions have finished, i.e., one of the reactants has been completely used up and therefore no more gas is produced. Both finished with the same amount of gas produced, as both reactions had the same amount of reactants to start with.

2011: 2 RATES OF REACTION

Calcium carbonate (marble chips) and hydrochloric acid react together in a conical flask. The word equation for this reaction is:

\[
\text{calcium carbonate + hydrochloric acid} \rightarrow \text{calcium chloride + water + carbon dioxide gas}
\]

(a) Describe an observation you would make when this reaction occurs.
The mass of the flask and contents is measured on a scale over time and recorded on the graph shown below.

Fizzing / bubbling occurs, marble chips decrease in size.

(b) Explain why the mass decreases with time.
In your answer you should:
• consider all the products being formed
• explain what is happening, in terms of particles AND the rate of reaction, in each section of the graph.

The mass decreases with time because……

In section X:
In section Y:
In section Z:

Why mass decreases
The marble chips decreases as one of the products is CO₂ gas. This gas escapes and so the mass of the flask and contents is reduced.

**What’s happening**

As the reactant particles collide, they form product particles. As the reaction proceeds, there are fewer and fewer reactant particles left to collide and so the rate of reaction becomes slower. At the start (section X) of the reaction, more product particles are being formed, therefore more gas escapes at first and so the mass of the flask and contents decreases more rapidly. At X, the rate of reaction is fast but decreasing with time. In section Y there are now fewer (less) reactants and so there are fewer collisions per second (unit time) and so less product is formed, ie less gas being released, so the mass does not decrease as rapidly. At Y, the rate of reaction is slow and slowing. In section Z the reaction has stopped, as one of the reactants (marble chips or HCl) has run out, so there are no particles left to react.

(c) When more concentrated hydrochloric acid is used, the reaction is faster.

Explain the difference in the rate of reaction. In your answer you should refer to:

- particles
- collisions
- reaction rate

When more concentrated acid is used, there are more acid particles in the same volume of the acid. Because of this, there are more particles to collide with the calcium carbonate. Because there are more to collide, the rate of reaction is faster (as more collisions/unit time).

**2011: 4 QUESTION FOUR: RATES OF REACTION (SAMPLE)**

Marble chips (calcium carbonate) are added to dilute hydrochloric acid in a conical flask. The flask is connected to an inverted measuring cylinder in a trough of water, as shown in the diagram below.

The volume of gas produced is measured over a few minutes, and the results used to sketch a graph.

(a) The slope of the graph is steep at the beginning and then levels off over time. Explain what is happening, in terms of particles, during the reaction.

Explanation of leveling of graph:
As the reactant particles collide, they are converted into product particles. Initially many gas molecules are produced, but as the reaction proceeds there are fewer and fewer reactant particles available to collide, so the volume of gas produced decreases and eventually no gas is produced. (Most likely the supply of H+ ions in the solution will be exhausted before the marble chips disappear.)

(b) Complete the word and symbol equations below to show the reaction in the experiment.

Word equation:

- Hydrochloric acid + calcium carbonate \( \rightarrow \) calcium chloride + water + carbon dioxide

Balanced symbol equation:

\[
2\text{HCl} + \text{CaCO}_3 \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2
\]

(c) The experiment is repeated but this time the same mass of marble chips is crushed into a powder before it is added to the flask.

Discuss the effect on the reaction rate of using powdered marble with hydrochloric acid compared with using marble chips. In your answer, you should:

- compare the rates of reaction
- explain the differences in the reaction rate by discussing how crushing the marble chips affects the number of particle collisions.

Comparison of rates of reaction:
The reaction rate will be faster with the powdered marble than when the chips were used. More gas will be produced each minute. The reaction itself will be completed in a shorter period of time.

Explanation of effect:
There are more reactant particles immediately available to react because the surface area of the powder is greater than that of the chip. There is greater exposure of the marble particles so there are more available for the acid particles / hydrogen ions / H⁺ ions to collide with. This means there will be more (effective) collisions per second / more frequent collisions between the acid particles and the ions in the calcium carbonate powder, leading to an increase in the rate of the reaction and the reaction will be completed sooner.