Rates of Reaction Notes

Science Exams Sorted www.scienceexamssorted.co.uk

The rate of a reaction is just a measure of how quickly the reactants are converted into products. The faster this happens, the higher the rate of reaction. But how does a chemical reaction actually happen?

Particles must collide in order to react. This is collision theory 😊

Collision Theory

What is collision theory? Collision theory is an explanation for how and why chemical reactions occur. Collision theory states that for a reaction to take place, particles of the reactants must collide under the right conditions.

What factors affect collision theory? The frequency of collisions (the number of collisions that happen in a period of time) and the energy of collisions. If a reaction has a high frequency of collisions and the particles have plenty of energy then the rate of reaction will be high.

Do all collisions result in a reaction? No, not all. If particles don't have enough energy when they collide then they won't react. Think of it in terms of a hammer and nail. If we hit the nail with only a tiny whack from the hammer, nothing will happen! We need to really hit the nail with the hammer to actually drive the nail in.

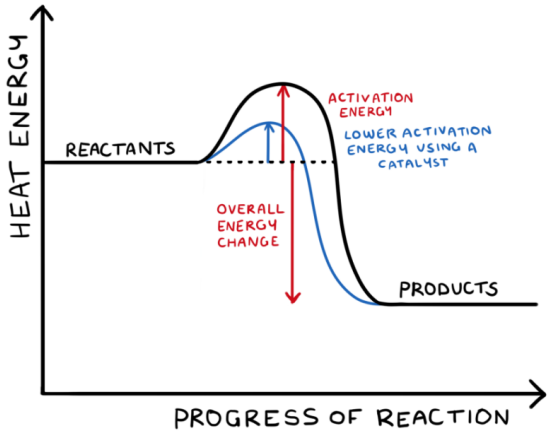
Is there a minimum energy for a reaction to occur? Yes it's called the activation energy. The activation energy is the minimum energy required for a reaction to occur.

Factors Affecting the Rate of Reaction

The rate of a chemical reaction can be affected by five factors. They are increasing the concentration, temperature, surface area and pressure in a reaction as well as using catalysts. How does each factor work?

1. **Concentration –** increasing the concentration means there are more reactant particles in the same volume (they are closer together). This leads to **more frequent collisions between reactant particles**.
2. **Temperature** – increasing the temperature of the reactants gives the particles more kinetic energy. Particles move faster, leading to more frequent and energetic collisions. **More particles have** energy that is greater than or equal to **the activation energy**. This results in a greater frequency of successful collisions, increasing the rate of reaction.
3. **Surface Area** – if the reactants are solids, increasing the surface area means more particles are available for collisions to happen. This **increases the frequency of collisions** and speeds up the reaction.
4. **Pressure** – if the reactants are gases, increasing the pressure of the reactants reduces the space between particles. This means that the **frequency of collisions increases so the rate of reaction will be higher**.
5. **Catalysts** – catalysts **provide an alternative reaction pathway that has a lower activation energy**. This will reduce the energy that we need to add to get the reaction going. They are not used up in the reaction.

   The figure below shows the reaction profile for the effect of adding a catalyst. Please do make sure you learn this figure as it has come up as a question many times.



Note: the blue line shows the reaction happening at a lower activation energy.

But notice that both reaction lines start and end at the same points. Only the activation energy is different.

Measuring Rates of Reaction

We could be asked how we could measure the rate of a reaction for an experiment. How we do it will depend on the type of reaction we're doing. There are two standard options that we would go for.

1. **Measuring the volume of gas produced** – if we're doing a practical where a gas is produced and we're collecting that gas, then this is a good option. The faster a certain volume of gas is produced, the higher the rate of reaction.

2. **Measuring the change in mass during the reaction** – if you're doing a practical where carbon dioxide is produced and leaves the reaction then the mass (do not say weight) decreases. The quicker that the mass changes the higher the rate of reaction for that experiment.

3. **Measuring the time taken for a colour change or precipitate to form** - if the reaction produces a solid precipitate that clouds the solution, you can time how long it takes for a mark (like a drawn 'X') to disappear under the flask.

Calculating Rates of Reaction

We could see questions where we are asked to calculate the rate of reaction. Typically these kinds of questions involve graphs and we will look at those but first let's look at the formula to calculate rates of reaction.

$$\boldsymbol{Rate\ of\ Reaction = \frac{change\ in\ the\ amount\ of\ reactant\ or\ product}{time\ taken\ for\ that\ change}}$$

Let's have a look at a couple of examples.

Example 1: A chemical reaction produces 60 cm^3 of gas in 3 minutes. Calculate the rate of reaction.

$$Rate\ of\ Reaction = \frac{60}{3}$$

$$Rate\ of\ Reaction = 20\ cm^3/min$$

Example 2: A reaction between magnesium ribbons and hydrochloric acid produces 240 cm^3 of hydrogen gas over 80 seconds.

a. Calculate the rate of reaction in cm^3/s.

$$Rate\ of\ Reaction = \frac{240}{80}$$

$$Rate\ of\ Reaction = 3\ cm^3/s$$

b. If the volume of hydrogen gas doubles in the next 40 seconds, what is the average rate of reaction for this period?

Step 1: find what double 240 cm^3 is. Yep, it's 480 cm^3.

Step 2: Find the difference between these two figures. $480 - 240 = 240\ cm^3$

Step 3: pop these values into the rate equation and solve.

$$Rate\ of\ Reaction = \frac{240}{40}$$

$$Rate\ of\ Reaction = 6\ cm^3/s$$

Rates of Reaction from Graphs

It's very safe to say that the majority of questions that ask us to determine the rate of a reaction involve graphs in one way or another. If we are asked to find the rate of reaction from a graph then we will have to find the gradient 😊

Quick note: this will depend on what type of rate we are looking for and this will vary from question to question. What are the types of rate and how do we find each? I'm glad you asked 😊

1. **Initial rate of reaction** – <u>is the rate of reaction at the very start of the reaction</u>, when the gradient of the graph is steepest. We find it by drawing a tangent to the curve at $\mathbf{t = 0}$ and getting the gradient of the tangent.

A quick reminder that gradient is calculated using the equation:

$$\boldsymbol{Gradient = \frac{change\ in\ y}{change\ in\ x}} \qquad \text{or...} \qquad \boldsymbol{Gradient = \frac{\Delta y}{\Delta x}}$$

2. **Instantaneous rate** – <u>is the rate of reaction at a specific point in time</u>. It is found by getting the gradient of the tangent to the curve at that specific point. These are the most common style of question that we see asked.

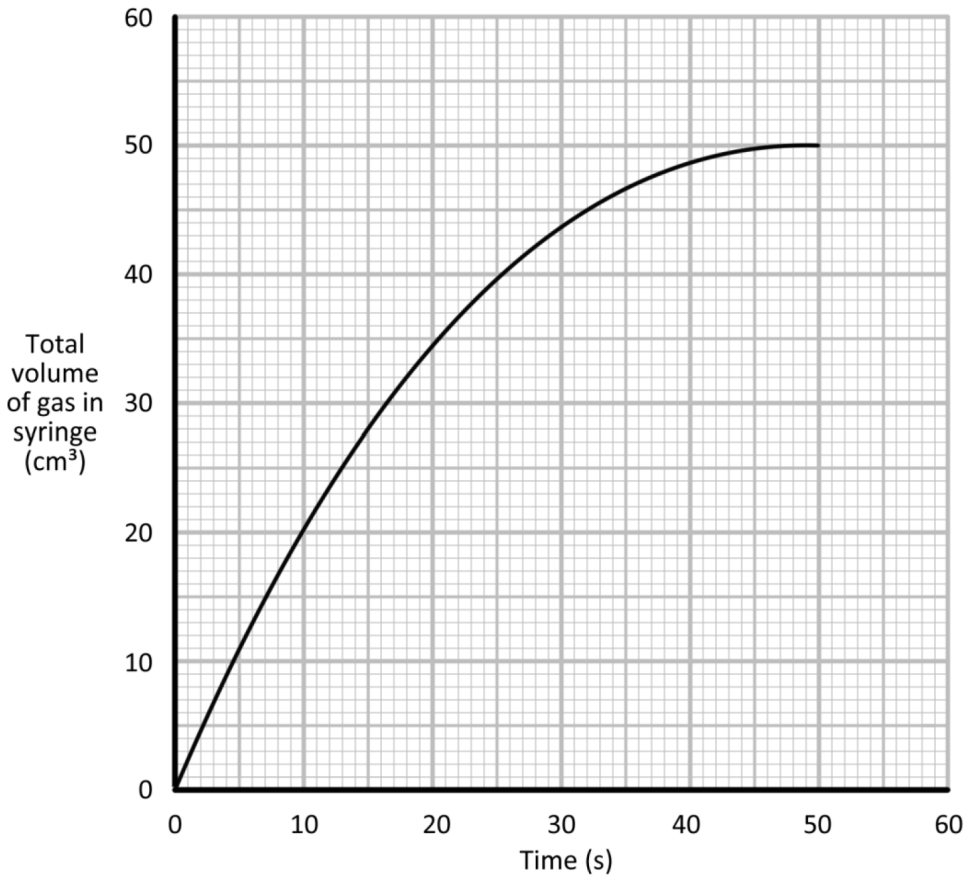
3. **Average rate** – <u>is the rate of reaction over a certain period of time</u>. We can find it by getting the gradient of a straight line connecting two points on the graph. This can be used to find the average rate for the whole reaction if we want or are asked.

Exam note: recently graph questions where we would normally need to draw the tangent to find the gradient are coming with the tangent pre drawn on for us. This will be one less thing for us to do but please make sure that you are happy using tangents to curves to find a gradient in case we do need to draw one.

Let's have a look at an example of one of these graph gradient questions 😊

Example 3: A student investigates the rate of reaction between large marble chips and dilute hydrochloric acid. The student measures the volume of carbon dioxide gas given off every 10 seconds.

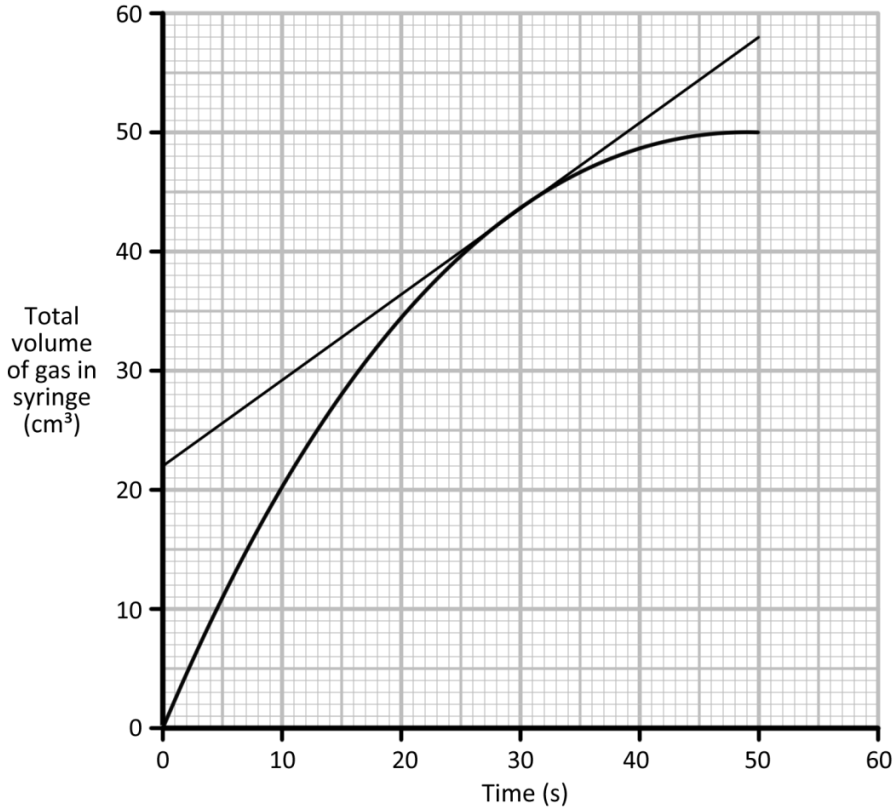
The graph shows the student's results.



Use the tangent to calculate the rate of reaction at 30 seconds.

Step 1: draw a tangent to the curve at 30 seconds. Please do this in pencil in case you need to change it.

Step 2: use the equation $\boldsymbol{Gradient} = \frac{\Delta \boldsymbol{y}}{\Delta \boldsymbol{x}}$



$$Gradient = \frac{58 - 22}{50}$$

$$Gradient = \frac{36}{50}$$

$$Gradient = 0.72 \text{ cm}^3/\text{s}$$

Therefore the rate of reaction at 30 seconds is 0.72 cm^3/s.