17 How fast? The rate of chemical change

Teaching plan

Sub-chapter	Approximate number of learning hours	Learning content	Resources
17.1 What is 'rate' of reaction? 17.2 Experiments to measure the rate of reaction	1–2	The rate of reaction is expressed as the change in concentration of a particular reactant / product per unit time. Determination of rates of reaction.	**Coursebook** Sections 17.1–17.2 **Workbook** Exercises 17.1–17.2 **Teacher's resource** PowerPoint 17, slides 3–4 End of Chapter 17 test
17.3 Collision theory 17.4 Factors affecting reaction rate	3–5	Species react as a result of collisions of sufficient energy and proper orientation. Explanation of the relationship between the kinetic energy of the particles and the temperature in kelvin and the role of collision geometry. Activation energy, E_a, is the minimum energy that colliding particles need for successful collisions to lead to a reaction. Factors that influence the rate of a reaction include temperature, pressure / concentration, surface area and the presence of a catalyst. Catalysts increase the rate of reaction by providing an alternative reaction route with lower E_a.	**Coursebook** Sections 17.3–17.4 Test your understanding Questions 1–6 **Workbook** Exercises 17.3–17.4 **Teacher's resource** PowerPoint 17, slides 5–8 End of Chapter 17 test

Sub-chapter	Approximate number of learning hours	Learning content	Resources
17.5 The rate equation 17.6 Mechanisms of reactions 17.7 Variation of the rate constant with temperature	2–3	Many reactions occur in a series of elementary steps, and the slowest step determines the rate of the reaction. Energy profiles can be used to show the activation energy and transition state of the rate-determining step in a multi-step reaction. The molecularity of an elementary step is the number of reacting particles taking part in that step. Rate equations depend on the mechanism of the reaction and can only be determined experimentally. The order of a reaction describes, with respect to a reactant, the number of particles taking part in the rate-determining step. The rate constant, *k*, is temperature dependent and its units are determined from the overall order of the reaction. The Arrhenius equation uses the temperature dependence of the rate constant to determine the activation energy. The Arrhenius factor, *A*, takes into account the frequency of collisions with proper orientations.	**Coursebook** Sections 17.5–17.7 Test your understanding Questions 7–24 **Workbook** Exercises 17.5–17.7 **Teacher's resource** End of Chapter 17 test

BACKGROUND KNOWLEDGE

- Students should be aware of the units of concentration from the stoichiometry topic covered in Chapter 16.
- Students may have covered some aspects of rates of reaction in pre-IB courses. This topic will build upon this knowledge.

Syllabus overview

- Students will understand the concept of a rate of reaction and how it can be measured. They will then use collision theory to explain how the different factors (temperature, pressure / concentration, surface area, catalyst) affect the rate of reaction. They will also understand how a catalyst works.
- Higher Level students will be able to explain orders of reactions, using reaction mechanisms, and calculate activation energies using the Arrhenius equation.

17.1 What is 'rate' of reaction? and 17.2 Experiments to measure the rate of reaction

LEARNING PLAN

Learning objectives	Success criteria
Understand what is meant by the rate of a reaction	Students can explain what is meant by the rate of a reaction.
Understand how to calculate rates of reaction	Students can calculate rates of reaction.

Common misconceptions

Misconception	How to identify	How to overcome
Students get the units of rate of reaction confused.	Practice questions should highlight if they use the wrong units.	Always ask students to show the units for the rates of reaction. Highlight the different units that may be used for rate calculations.

Starter ideas

1 Demonstration of a rate of reaction (20 minutes)

Resources: Equipment and chemicals for the elephant's toothpaste demonstration. See links to a video and instructions that can be used in the digital resources section.

Safety: A risk assessment should be written before doing this practical.

Description and purpose: Students can see how something can affect the rate of reaction.

What to do next: Students discuss what has caused the rate of reaction to change as a class.

Main teaching ideas

1 How to measure the rate of a reaction (45 minutes)

Resources: Diagrams of different practical experiments showing how to measure rates of reaction. Chemicals and apparatus provided for a simple rate of reaction practical (e.g., magnesium and hydrochloric acid)

Description and purpose: The teacher explains the different ways to measure the rate of reaction: measuring the volume of gas over time, measuring the change in mass over time, or how long it takes for the reaction to change colour. Diagrams of the practical setup are shown, so students know which equipment is used. A simple rate of reaction practical (e.g., magnesium ribbon and acid) could be done to measure the rate, or students can be given some data to work out the rate of reaction. The teacher should explain how to draw a tangent from the graph, to get the initial rate of reaction and the rate at any one moment during a reaction.

Safety: A risk assessment needs to be carried out first.

Differentiation ideas:

Support: The teacher can demonstrate the practical work and talk through how to do the calculations to find out the rate of the reaction.

Stretch and challenge: For the practical, students are not given any instructions, and they have to work out for themselves how to measure the rate of reaction.

Plenary ideas

1 Write out a practical method to find out a rate of reaction (10 minutes)

Resources: List of chemicals and equipment available in the laboratory that they could use for their practical work.

Description and purpose: Students are asked to write out a practical method to find out the rate of a reaction. Students can be given the details for the reactants, which may help them to decide which method to use. This can link to other practical work, and they should ensure that they include control variables to make it a fair test. They could also give instructions for how to calculate the rate of reaction.

› **Language focus:** Writing out a clear and distinct method.

17.3 Collision theory and 17.4 Factors affecting reaction rate

LEARNING PLAN

Learning objectives	Success criteria
Explain collision theory	Students can explain collision theory.
Explain the factors that affect the rate of a reaction	Students can explain the factors that affect the rate of a reaction.
Explain the effect of temperature on the rate of reaction	Students can explain the effect of temperature on the rate of reaction.
Explain the effect of a catalyst on the rate of reaction	Students can explain the effect of a catalyst on the rate of reaction.

Common misconceptions

Misconceptions	How to identify	How to overcome
Students do not talk about particles when explaining collision theory.	Ask students for explanations in class. Get students to expand on each other's answers to check the understanding of the class.	Give students model answers they can adapt and learn from before they try answering these types of questions.
Students get confused between the different explanations of collision theory for different factors.	Students can be given questions that will test their knowledge in this area.	Students can create a mind map that separates out the different factors and give an explanation for each one.

Starter ideas

1 Collision theory (15 minutes)

Resources: Two apples.

Description and purpose: Show students two apples and gently touch them together. When pulled apart they appear the same. Do the same thing with more force and the apples are crushed. This demonstration leads into a discussion that you need a collision of sufficient energy for a reaction to occur.

What to do next: Students could look at some computer models or diagrams of particles reacting, showing that a collision of sufficient energy must take place for a reaction to occur. The teacher could also expand on this and explain that the correct orientation of the molecules is also required.

› **Language focus:** The students can explain collision theory using the correct terminology.

Main teaching ideas

1 Factors that affect the rate of reaction (40–120 minutes)

Resources: Chemicals and apparatus for different rates of reaction practicals.

Description and purpose: Students can do different experiments to look at the different factors that affect the rate of reaction. Calcium carbonate powder, marble chips and acid could be used to look at how changing surface area and / or concentration affects the rate of reaction.

Safety, *if applicable:* All experiments need to have had a risk assessment before they are done.

› **Differentiation ideas:**

Support: Students are given a clear step-by-step method with guiding questions.

Stretch and challenge: Students use collision theory to explain how these changes affect the rate of reaction.

2 Factors that affect the rate of reaction (40–120 minutes)

Resources: Worksheet 17.1.

Description and purpose: Students can do different experiments to look at the different factors that affect the rate of reaction. Sodium thiosulfate and HCl could be used to look at concentration and temperature, and the teacher could demonstrate with KI and hydrogen peroxide to look at catalysts. The teacher then explains why these factors affect the rate of reaction using energy profile diagrams and Maxwell–Boltzmann distributions, where appropriate.

Safety, *if applicable:* All experiments need to have had a risk assessment before they are done.

› **Differentiation ideas:**

Support: Students are given a clear step-by-step method with guiding questions.

Stretch and challenge: Students come up with their own methods for the practical work and come up with their own explanations as to how these factors affect the rate of reaction.

3 Factors that affect rates of reaction questions (30 minutes)

Resources: Rates of reaction questions.

Description and purpose: Students are given questions about the factors that affect the rate of reaction.

› **Differentiation ideas:**

Support: Students can be given answers to the questions and asked to work out which answer goes with which question.

Stretch and challenge: Students write their own questions and answers, based on the syllabus points, to show their full understanding of the topic.

Plenary ideas

1 Pamphlet on collision theory (15 minutes)

Description and purpose: Students produce a pamphlet explaining collision theory and how each factor affects the rate of reaction.

› **Assessment ideas:** They can work in pairs and, once completed, the students can swap with another pair and read what they have written and peer assess it. This will help the students with any misconceptions they have.

› **Language focus:** Producing written information that others can understand using the proper terminology.

17.5 The rate equation; 17.6 Mechanisms of reactions and 17.7 Variation of the rate constant with temperature

LEARNING PLAN

Learning objectives	Success criteria
Deduce rate equations for reactions and calculate rate constants	Students can deduce rate equations for reactions and calculate rate constants.
Sketch concentration–time and rate–concentration graphs	Students can sketch concentration–time and rate–concentration graphs.
Understand the connection between the rate equation and the reaction mechanism and evaluate reaction mechanisms	Students can explain the connection between the rate equation and the reaction mechanism and evaluate reaction mechanisms.
Draw energy profiles for reactions	Students can draw energy profiles for reactions.
Understand the effect of temperature on the rate constant	Students can explain the effect of temperature on the rate constant.
Calculate the activation energy and Arrhenius *A* factor (pre-exponential factor)	Students can calculate the activation energy and Arrhenius *A* factor (pre-exponential factor).

Common misconceptions

Misconceptions	How to identify	How to overcome
Students get confused with linking the mechanism to the order of the reaction	Examples in class on reaction mechanisms	Go through a reaction mechanism and highlight the slow step of the reaction, and get the students to count up the reactants – up to and including that point – to deduce the rate expression and order of the reaction.
Students use the incorrect values for temperature when calculating activation energy	Ask students to work out activation energy, giving them the rate constant and temperature (in °C) data	Explain that temperature needs to be in kelvin.

Starter ideas

1 Order of reaction (10 minutes)

Resources: Graphs of concentration against time and rate against concentration for different orders of reaction.

Description and purpose: Discuss the graphs of concentration against time and rate against concentration for different orders of reaction and explain why they look like they do.

What to do next: The students can use these to come up with an overall rate equation for each order of reaction.

Main teaching ideas

1 Determining the order of reaction and the rate equation from experimental data (40 minutes)

Description and purpose: The teacher gives the students some experimental data to work out the order of reaction and the rate equation. The teacher explains how to approach the calculation, going through how to get the order of the reaction with respect to the reactants, the rate equation, and the rate constant with units. The students are then given similar questions to try on their own.

› **Differentiation ideas:**

Support: The students can be grouped, and the teacher can spend more time with those groups that need extra help with the questions.

Stretch and challenge: Students can be given questions where data are not as easy to interpret and there are more reactants.

2 Activation energy practical (25 minutes)

Resources: Use the Pearson qualifications website for instructions on a practical on activation energy.

Safety: A risk assessment needs to be completed by the teacher before the lesson.

Description and purpose: Students complete a practical to find out the rate of reaction at different temperatures. Once they have worked out k for each temperature, they can then plot a graph of $\frac{1}{T}$ against $\ln k$. From the gradient, the students will then be able to work out the activation energy for the reaction.

› **Differentiation ideas:**

Support: Rather than complete the practical, students can be given data to use. This will give them more time to go through the calculation.

Stretch and challenge: Extra questions on activation energy can be given.

Plenary ideas

1 Exam-style questions (40 minutes)

Resources: Exam-style questions or past paper questions on the topic.

Description and purpose: Students will get an opportunity to see some exam-style questions. This will help them understand the type of questions that get asked and the style in which they are asked. The teacher will be able to assess their learning from the topic, and the students will see which areas they need to focus on.

Assessment ideas

- Students could be given an assessed practical experiment to work out the activation energy of a reaction.
- Past paper questions on this topic.
- End of Chapter 17 test.

Homework ideas

- Questions from the Coursebook.

  › **Language focus:** Write out revision flash cards on this topic.

  › **Language focus:** Students could go through the end of chapter test and highlight any errors they made, creating a list of areas of weakness, which may include the following: not reading the question, lack of detail, incorrect use of vocabulary, lack of knowledge and silly mistakes. From this, the students can make a revision plan to help improve their understanding of the topic.

- Students can use the reflection checklist from the Coursebook to check their understanding of the topic.

Links to digital resources

- Instructions and demonstration of the elephant's toothpaste experiment

CROSS-CURRICULAR LINKS

- Maths: Using exponential functions and natural logs during calculations where the students need to manipulate the Arrhenius equation to work out the activation energy.