1 The particulate nature of matter

Teaching plan

Sub-chapter	Approximate number of learning hours	Learning content	Resources
1.1 Elements, compounds and mixtures	2–3	Recall the definitions of elements, compounds and mixtures. Distinguish between the properties of an element, compound or mixture. Understand the difference between homogeneous and heterogeneous mixtures. Describe experimental techniques to separate mixtures.	**Coursebook** Section 1.1 Test your understanding Questions 1 and 2 **Workbook** Exercise 1.1 **Teacher's resource** PowerPoint 1, slides 2–6 Worksheet 1.1 Questions 1, 3 and 5, End of Chapter 1 test Questions 1–6, 9–10
1.2 Kinetic molecular theory 1.3 Temperature and kinetic energy 1.4 Changes of state	2	Determine the state symbols in chemical equations. Recall the names of the changes of state. Explain the physical properties of matter and changes of states using kinetic molecular theory. Understand that temperature in kelvin is a measure of average kinetic energy of particles. Know how to convert between Celsius and Kelvin scales.	**Coursebook** Sections 1.2–1.4 Test your understanding Question 11 **Workbook** Exercises 1.2–1.4 **Teacher's resource** PowerPoint 1, slides 7–8 Worksheet 1.1 Questions 2 and 4 End of Chapter 1 test Questions 7–8

BACKGROUND KNOWLEDGE

- Understand how to classify substances as elements, compounds or mixtures.
- Describe simple techniques for separating mixtures (filtration, distillation, evaporation and paper chromatography).
- Draw particle diagrams and use them to explain the properties of solids, liquids and gases.
- Know the names of the interconversions of the three states of matter.
- Know there are two different scales for measuring temperatures: degree Celsius and Kelvin.
- Know how to use a data logger and a temperature probe, plot line graphs and draw lines of best fit.

Syllabus overview

- The first part of the syllabus covers the concepts of elements, compounds, mixtures and the application of kinetic molecular theory to explain the particle models of states of matter. Students need to know the differences between compounds and mixtures and how to construct names and formulas of compounds. This will facilitate the study of chemical reactions using balanced symbol equations and how to solve problems using molar ratios of reactants and products (Chapters 4 and 16).
- There are many opportunities for students to practice fundamental laboratory techniques, covering the various methods for separating mixtures. Students should be encouraged to think about how to test for the purity of products after separation and research into how to purify products further. When measuring melting/cooling curves of substances, students also practice mathematical skills of presenting their data graphically and analysing the results to extract information on melting/boiling points.
- Simulations can be used to illustrate molecular movement of particles. This gives an introduction on how the kinetic energy of particles is distributed in a sample of gas at a fixed temperature and the concept of activation energy in a chemical reaction (Chapter 17).

1.1 Elements, compounds and mixtures

LEARNING PLAN

Learning objectives	Success criteria
Understand the terms element, compound and mixture	Students should be able to explain the terms element, compound and mixture and distinguish between them.
Understand the differences between heterogeneous and homogeneous mixtures	Students should be able to explain the difference between heterogeneous and homogeneous mixtures and give examples of each.
Understand how to separate the components of a mixture	Students should be able to explain the different methods for separating the components of a mixture and suggest a suitable method for separating a particular mixture.

Common misconceptions

Misconception	How to identify	How to overcome
Students confuse the meaning of compounds and molecules	Ask students to assign various names and formulas of elements and compounds to a Venn diagram of two circles labelled compounds and molecules.	Draw particle diagrams to show which names/formulas are molecules or compounds. Molecules can be elements (O_2) or compounds (H_2O) and only covalent compounds are molecules.
Students confuse physical and chemical changes	Show students pictures of different processes (for example, physical processes, including melting, freezing and sublimation, and chemical processes, including rusting, fireworks and cooking an egg) and ask them to distinguish the physical from the chemical changes.	A physical change is one in which no new chemicals are formed, for example, dissolving and changes of states. A chemical reaction involves making new substances. Teachers can demonstrate some examples when elements are combined in chemical reactions to form compounds. For example, burning Na in Cl_2 or Mg in O_2. Use particle diagrams to show that the microscopic make-up of the reactants and products is different, and the atoms are bonded together differently.

Starter ideas

1 Recap prior knowledge from pre-IB (10 minutes)

Resources: Test your understanding questions 1 and 2 in the Coursebook.

Description and purpose: Students define element, compound and mixture. They should then sort out the listed substances and diagrammatic representations into the three categories. This activity assesses students' prior knowledge.

What to do next: If most of the students can define element, compound and mixture and identify them correctly, teachers can ask them to give more examples of each. Make sure to emphasise the keywords in the definitions. If students find it difficult to distinguish amongst the three categories, help by pointing out that elements can be found in the periodic table, elements combine chemically to form compounds and give examples of names and formulas of various compounds. Most of things we meet daily are mixtures and can be separated by physical methods.

› **Language focus:** Learners are encouraged to pay attention to definitions of the key terms.

Main teaching ideas

1 Teacher demonstrations on the formation of compounds from constituent elements (20 minutes)

Resources: Search for the websites mentioned in the Description and purpose line for apparatus/chemicals required for each demonstration.

Description and purpose: Iron and sulphur (search the 'Royal Society of Chemistry' website with the keywords 'iron and sulfur reaction')

Sodium and chlorine (search the 'Royal Society of Chemistry' website with the keywords 'sodium and chlorine reaction')

These experiments can be performed to show how elements retain their properties in a mixture but change their properties when forming compounds. Ask students to record the observations (changes in physical states, colours, endothermic vs exothermic etc.) during the reaction and write word and symbol equations to represent the chemical processes.

Differentiation ideas

Support: Provide students with a table to record the appearance of the reactants and products of the reactions, and their observations during the reactions. Stress the importance of forming new substances in chemical reactions.

Stretch and challenge: Students can be asked to construct balanced chemical equations for these reactions with state symbols.

Language focus: Recording observations. This is one way of checking the correct use of terminology.

2 Student practical (2 × 45 minutes)

Resources: A mixture of sand and water, sodium chloride solution, a mixture of ink and water, a mixture of food dyes. Apparatus required for filtration (for example, funnel, filter paper, clamp, boss head, stand, beaker), simple distillation (for example, round-bottomed flask, thermometer, bung, Liebig condenser, beaker, Bunsen burner, heat-proof mat), evaporation (evaporating basin, gauze, Bunsen burner, heat-proof mat, tripod) and paper chromatography (chromatography paper, beaker, pencil, ruler, small capillary tube).

Description and purpose: Ask students to separate various mixtures, including sand and water (filtration), table salt dissolved in water (simple distillation to keep the water or evaporation to obtain only the salt crystal), ink and water (simple distillation), a mixture of food dyes (paper chromatography). The practical could be run at different stations set up around a laboratory.

Differentiation ideas

Support: Providing exact step-by-step methods with diagrams to guide students through the practical.

Stretch and challenge: Students design their own methods and carry out the experiments once their methods are approved by a teacher. Students can further research on the procedures and applications of solvation, recrystallisation, column and gas-liquid chromatography, and present their findings to the rest of the class.

Plenary ideas

1 How to separate mixtures (10 minutes)

Resources: Fill in the information in the following table on how to separate mixtures. The first two rows have been completed as an example.

Separation of …	Homogeneous or heterogeneous mixtures	Technique	Example
two liquids	homogeneous	simple distillation: the liquid with a lower boiling point will boil first	ink and water: water will boil first
two liquids	heterogeneous	two liquids that are immiscible and have different densities can be separated into layers in a separatory funnel	water and dichloromethane: dichloromethane is denser, so it will come out of the funnel first
a solid and a liquid	homogeneous		
a solid and a liquid	heterogeneous		
two solids	heterogeneous		

Answer: a solid and a liquid, homogeneous, simple distillation (to keep the liquid) or evaporation, sodium chloride solution
a solid and a liquid, heterogeneous, filtration, sand and water two solids, heterogeneous, solvation (finding a solvent which dissolves one of the two solids) followed by filtration and evaporation, rock salt (a mixture of sand and sodium chloride)

Description and purpose: This exercise gives students an opportunity to summarise, recall and apply their knowledge.

› **Language focus:** Take note of the language used when making a summary of the experimental methods.

1.2 Kinetic molecular theory; 1.3 Temperature and kinetic energy and 1.4 Changes of state

LEARNING PLAN

Learning objectives	Success criteria
Use kinetic molecular theory to understand the properties of solids, liquids and gases	Students should be able to explain the properties of solids, liquids and gases using kinetic molecular theory.
Understand that temperature in K is proportional to the average kinetic energy of particles	Students can recall that temperature in K is proportional to the average kinetic energy of particles.
Understand how to convert temperatures between K and °C	Students should be able to convert temperatures between K and °C.
Use state symbols in chemical equations	Students can apply state symbols in chemical equations.
Use kinetic molecular theory to explain changes of state	Students should be able to explain changes of state using kinetic molecular theory.

Common misconceptions

Misconception	How to identify	How to overcome
Students confuse boiling and evaporation	Ask students to explain the differences between boiling and evaporation.	In both processes, liquids change to gases. Boiling occurs at a particular temperature (boiling point) and throughout the whole of the liquid. Evaporation can occur at all temperatures but only on the surface of the liquid.
Changes in temperature on Kelvin and Celsius scales are muddled up	Ask students what is $\Delta T = 30$ °C when converted to Kelvin scale.	The intervals on both the temperature scales are the same, so the changes in temperature can have either K or °C as units but the numerical values remain the same. A change of 20 °C to 50 °C (30 °C) has the same value as a change of 293.15 K to 323.15 K (30 K) when converted to the Kelvin scale.
Students struggle to understand what is in the space between particles in the particle model	Show students a model of the giant ionic lattice of NaCl or a model of the molecular structure of ice and ask them what is in between the particles in the model.	Students often have the misconception that the space is filled with air. Air is a mixture of many gas molecules/atoms, and these entities are themselves too big to fit into the space between particles in the NaCl ions or H_2O molecules in the solid state.

Starter ideas

1 Solid, liquid and gas particle diagrams (10 minutes)

Resources: A piece of A4 paper showing three equal-sized square boxes.

Description and purpose: Students complete diagrams showing the arrangement of particles in a solid, liquid and gas and then name the processes for the changes of state. This activity recaps students' knowledge from pre-IB.

What to do next: Students should be clearly aware of how the particle arrangements are represented in these diagrams.

2 Recognise the states of matter based on melting and boiling points (10 minutes)

Resources: Test your understanding Question 11 in the Coursebook.

Description and purpose: Ask students to identify the states of matter at given temperatures. Students should be able to apply their knowledge of melting and boiling points to recognise the states of matter.

What to do next: Show the melting/boiling points on a number line to order them, if students find this activity difficult.

Main teaching ideas

1 Practical on the freezing of stearic acid (45 minutes)

Resources: A detailed list of apparatus and chemicals can be found by searching the 'Royal Society of Chemistry' website with the keywords 'freezing of stearic acid'. Graph paper is required for analysing the results.

Description and purpose: Students need to heat up 3 spatulas of stearic acid until it melts. Then allow the acid to cool and take a temperature reading every 10 seconds with a temperature probe and a data logger. Plot a graph of temperature of stearic acid (after it completely melts) against time. Ask students to explain the shape of the cooling curve and identify the freezing point of the acid.

› Differentiation ideas

Support: Provide a step-by-step method with a titled table to write down results. The temperature against time graph could be plotted using Google sheets or other software.

Stretch and challenge: Students can design their own method to carry out the experiment and plot data on a piece of graph paper.

2 Explanation of the changes of states of matter, using kinetic molecular theory (20 minutes)

Resources: Demonstrations showing changes of states (for example, ice melting, water boiling, steam condensing, dry ice subliming)

Description and purpose: Ask students to explain the changes of states of matter, in terms of the changes in the arrangement, movement and energy of the particles and the bonds in between the particles. Students will self-assess their explanations with keywords.

› Differentiation ideas

Support: Teachers can help students to review their answers and provide feedback on the use of keywords.

Stretch and challenge: Students can identify which processes are endothermic and which are exothermic.

Students can look into the different types of intermolecular forces and other types of bonding between particles.

Students can find out why sublimation occurs for some substances using the phase diagram.

› Language focus: Using scientific terminology and constructing logical long answers.

Plenary ideas

1 True or false (5 minutes)

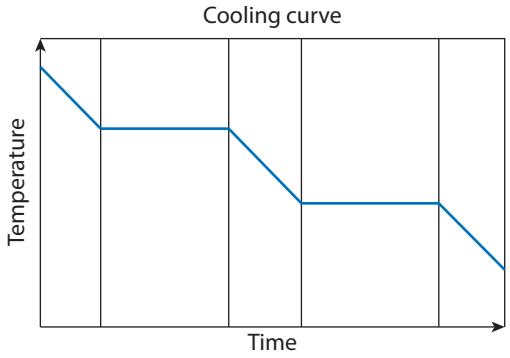
Resources: A table listing various properties of solids liquids and gases, for example:

	True	False
solids can be compressed		
liquids have no fixed volume		
gases have no fixed volume		
gases have a high density		
solids have fixed shape		
liquids can diffuse		

Description and purpose: Students mark true/false in the table. This activity allows students to apply their knowledge of the particle models to draw conclusion on the macroscopic properties of different states of matter.

2 Labelling a cooling curve and explaining the stages of temperature change using the kinetic molecular theory (10 minutes)

Resources: A cooling curve, for example,



Description and purpose: Students label the cooling curve with states of matter, changes of states, and identify the condensation and freezing points of the substance. Students also need to provide explanations on why temperature of the liquid goes down as cooling occurs but stays constant during freezing.

Assessment ideas

- Ask students to give examples of elements, compounds, mixtures, solids, liquids and gases around the classroom/lab.
- Suggest a suitable method for separating different types of mixtures.
- Label diagrams of lab apparatus and set-ups for filtration, evaporation, distillation and solvation.
- Students can design and carry out an experiment to obtain pure salt from rock salt.
- Calculations involving conversions between Celsius and Kelvin temperature scales.
- Label the different stages of a melting and boiling curve.
- Test your understanding questions from the Coursebook.
- Define keywords from the chapter.
- Explain the changes of states that occur during separation of mixtures. Ask students to use Post-it notes to assess their peers' answers.
- Give students explanations (containing common mistakes, missing out keywords) on the changes in the states of matter using the kinetic molecular theory and ask them to mark against a mark scheme.

Homework ideas

- Exam-style questions from the Coursebook.
- Exercises 1.1–1.4 from the Workbook.
- Carry out a paper chromatography experiment at home to separate the dyes in sweets. An example can be found by searching the 'Royal Society of Chemistry' website with the keywords 'chromatography of sweets'.
- Use Word Art to create an image for all the keywords in this chapter.
- Create flashcards on definitions of elements, compounds and mixtures and the different techniques used for separating components of mixtures.
- Sorting cards into solids, liquids and gases, or elements, compounds and mixtures. An example can be found by searching the 'Royal Society of Chemistry' website with the keywords 'lesson plans' and 'particle models'.

Links to digital resources

- Demonstrations on chemical changes (forming compounds from elements): Iron and sulphur – search the 'Royal Society of Chemistry' website with the keywords 'iron and sulfur reaction'. Sodium and chlorine – search the 'Royal Society of Chemistry' website with the keywords 'sodium and chlorine'
- Experiment on freezing stearic acid: search the 'Royal Society of Chemistry' website with the keywords 'freezing of stearic acid'
- Simulations on particle movements during changes of states: search on the PhET website for 'states of matter simulation'
- Home experiment to separate dyes in sweets using paper chromatography: search the 'Royal Society of Chemistry' website with the keywords 'chromatography of sweets'
- Revision notes on kinetic molecular theory and the states of matter (2016 syllabus): search on ibchem.com with the keywords 'kinetic molecular theory' and 'states of matter'
- Introduction to the phase diagrams: search on the internet using keywords 'phase diagram'

CROSS-CURRICULAR LINKS

- Maths: Basic arithmetic calculations, plotting and interpreting graphs.
- Physics: Use and convert between Kelvin and Celsius temperature scales. Molecular theory of solids, liquids and gases. Describe phase changes using particle behaviour.
- TOK: How does scientific knowledge progress?