10 The periodic table

Teaching plan

Sub-chapter	Approximate number of learning hours	Learning content	Resources
10.1 The periodic table	1–2	Know the periodic table is arranged into periods, groups and blocks. Know what the period number and the group number show in terms of an element's electron configuration. State the positions of metals, non-metals and metalloids and the groups of alkali metals, halogens, noble gases, transition elements in the periodic table.	**Coursebook** Section 10.1 **Workbook** Exercise 10.1 **Teacher's resource** PowerPoint 10, slides 2–3
10.2 Periodicity 10.3 The chemistry of Group 1 and Group 17	2	Describe and explain the vertical and horizontal trends in the periodic table for atomic radius, ionic radius, ionisation energy, electron affinity and electronegativity. Describe and explain the trends in the metallic character of Group 1 elements and the non-metallic character of Group 17 elements.	**Coursebook** Sections 10.2–10.3 Test your understanding Question 7 **Workbook** Exercises 10.2–10.3 **Teacher's resource** PowerPoint 10, slides 4–10 Worksheet 10.1 Questions 1–3, 5–6 End of Chapter 10 test Questions 1–3, 5–8 and 14
10.4 Oxides	1–2	Describe the change in oxides from basic through amphoteric to acidic across a period. Construct equations for the reactions between oxides of Group 1 and 2 metals, carbon, sulfur with water. Understand that non-metal oxides can cause acid rain and ocean acidification.	**Coursebook** Section 10.4 Test your understanding Question 15 **Workbook** Exercise 10.4 **Teacher's resource** PowerPoint 10, slides 11–12 End of Chapter 10 test Question 9

Sub-chapter	Approximate number of learning hours	Learning content	Resources
10.5 Oxidation state	1–2	Explain the definition of the oxidation state. Know the general guidelines for assigning oxidation states to elements in an ion or a compound and the exceptions. Name ionic compounds using oxidation states.	**Coursebook** Section 10.5 Test your understanding Question 20 **Workbook** Exercise 10.5 **Teacher's resource** PowerPoint 10, slides 13–14 Worksheet 10.1 Question 4 End of Chapter 10 test Questions 4 and 10
10.6 Exceptions to the general increase in first ionisation energy across a period 10.7 The transition elements	4	Explain the exceptions in first ionisation energy across periods 2 and 3. Define what a transition metal is and list the properties of transition elements. Explain why transition elements have variable oxidation states and how they form complex ions with ligands. Explain why complexes of transition elements are coloured.	**Coursebook** Sections 10.6 and 10.7 **Workbook** Exercise 10.6–10.7 **Teacher's resource** PowerPoint 10, slides 15–17 Worksheet 10.1 Questions 3–4 End of Chapter 10 test Questions 11–13 and 15

BACKGROUND KNOWLEDGE

- The arrangement of elements in periods, groups and blocks based on their electron configurations (Chapter 3).
- Understand how to distinguish between metal and non-metal elements using their electrical conductivity and the acid–base character of oxides.
- Know the position of metals and non-metals in the periodic table.
- Explain why elements in the same group have similar chemical properties.
- Understand why the noble gases are generally unreactive.
- Know the basic physical properties and their trends for Group 1 and Group 17 elements.
- Know the basic chemical reactions of Group 1 (reactions with air and water) and Group 17 elements (displacement reactions) and the trends in their chemical properties. Recall the general reactions of acids with metals, bases and metal carbonates. Know that metal oxides can act as bases.
- Understand how to plot graphs to show linear relationships and interpret these graphs.

Syllabus overview

- Before the start of this chapter, students should have a solid grasp of knowledge on atomic structure (Chapter 2) and electron configurations (Chapter 3) and be able to discuss independently the arrangements of elements in periods, groups and blocks.
- The general trends in first ionisation energy across a period and down a group are covered in Chapter 3. In this chapter, the periodicity of other physical properties, including atomic and ionic radii, electron affinity and electronegativity, are discussed, including the exceptions in electron affinity. The chemical properties of Group 1 and 17 elements are demonstrated and explained.
- Students need to be able to recognise the metals, non-metals and metalloids in the periodic table. They should know the differences in bonding and structures of metal and non-metal oxides from Chapters 6 and 7. The chemical properties of these oxides are discussed in this chapter, and students can research further into the environmental impacts of non-metal oxides, for example, acid rain and ocean acidification.
- The concept of the oxidation state is introduced here for the purpose of naming compounds. The assignment of oxidation states requires knowledge of electronegativity (Chapter 7). Oxidation states are used for analysing redox reactions and assigning oxidising / reducing agents in Chapter 20.
- The physical properties of transition elements are discussed in Chapter 8. To understand the characteristic chemical properties of these elements, students need to have prior knowledge of coordination bonds and the shapes of molecules discussed in Chapter 7. The investigation of colours of transition element complexes can be linked back to Chapter 4 on plotting calibration curves and using them to find the concentrations of a coloured solution.

10.1 The periodic table

LEARNING PLAN

Learning objectives	Success criteria
Describe the structure of the periodic table	Students should be able to describe the structure of the periodic table in terms of periods, groups and blocks.
Deduce the electron configuration of an element from its position in the periodic table	Students can write the electron configuration of an element from its position in the periodic table.

Common misconceptions

Misconceptions	How to identify	How to overcome
Students think elements are arranged in the periodic table by increasing atomic mass.	Ask students to list the atomic number and the relative atomic mass of the first 20 elements and then conclude how the elements are ordered in the periodic table.	Argon (element 18) has a higher relative atomic mass than potassium (element 19) but is placed in front of potassium in the periodic table. In Mendeleev's version of the periodic table, elements are grouped together due to their similarities in chemical properties. This depends on the number of electrons, which is the same as the number of protons in an atom.

Misconceptions	How to identify	How to overcome
		The number of neutrons has no effect on the chemical properties.
Students use a single property to classify elements as metals or non-metals, rather than a range of information.	Show students a sample of graphite and ask whether it is a metal or a non-metal.	Graphite is shiny and can conduct electricity. However, its oxide (carbon dioxide) is acidic, and it is brittle. This shows that we should consider a range of properties before classifying something as a metal or a non-metal.

Starter ideas

1 Recap prior knowledge from pre-IB and Chapter 3 on the periodic table (10 minutes)

Resources: A periodic table.

Description and purpose: Students identify the periods and groups of some elements (for example, Li, P, Cu, Yb).

What to do next: If the majority of students can correctly state the periods and groups of a few elements, revise and further introduce the names of specific groups of elements in the periodic table, including alkali metals, halogens, noble gases, and transition elements.

2 s, p, d and f blocks (10 minutes)

Resources: A periodic table.

Description and purpose: Students write out the electron configurations of a few elements from s, p, d and f (for extension) blocks, so they can recognise why the elements are in their specific blocks of the periodic table.

What to do next: Students can assign elements to their respective blocks. For example, alkali metals – s block, halogens – p block. Mention that d-block elements are not always transition elements.

Main teaching ideas

1 Metals, metalloids and non-metals (40 minutes)

Resources: A periodic table, sub-chapter 10.1 of the Coursebook or the internet.

Description and purpose: Students can research examples and typical properties (colour, conductivity of heat and electricity, malleability, melting points and boiling points) of the three types of elements (metals, metalloids and non-metals). Each group of students should focus on one type of element and then present their findings to the rest of the class.

› **Differentiation ideas:**

Support: Provide students with a list of elements. For example, in Group 14, carbon as a non-metal, silicon and germanium as metalloids, and lead and tin as metals.

Stretch and challenge: Research metalloids, for example, antimony and tellurium; gather evidence on whether they should be classified as metalloids or metals / non-metals.

› **Language focus:** Students successfully present a clear and succinct summary of the properties of three types of elements and apply key terminology correctly.

2 Elemental sudoku (20 minutes)

Resources: Search the Royal Society of Chemistry website with the keywords 'elemental sudoku'; there are three puzzles of different levels of difficulty.

Description and purpose: This activity allows students to logically solve puzzles, applying their knowledge of the groups of elements in the periodic table.

Differentiation ideas:

Support: Start from easy puzzle 1; students can be allocated into mixed-ability groups and work collaboratively. The teacher can give hints on which row / column to solve first.

Stretch and challenge: Students can attempt the more difficult puzzles 2 and 3 and can make their own puzzle for their peers to solve.

Plenary ideas

1 Spot the mistakes in the table (10 minutes)

Resources: A table of elements as follows:

Elements	Group	Period	Block
Be	2	1	s
Mn	2	3	s
Ge	4	3	p
Po	14	6	f

Description and purpose: This exercise gives students an opportunity to apply their knowledge and requires them to pay attention to details.

2 Periodic table bingo (10 minutes)

Resources: Periodic table bingo cards and a periodic table; search the internet with the keywords 'periodic table, bingo', or prepare an alternative version.

Description and purpose: Teachers can choose which clues to give out in order to adjust the levels of difficulty of the game. This is a useful exercise for consolidating students' knowledge on the properties and uses of elements.

10.2 Periodicity and 10.3 The chemistry of Group 1 and Group 17

LEARNING PLAN

Learning objectives	Success criteria
Explain the trends in the properties of elements down a group and across a period	Students can describe and explain the trends in the properties of elements down a group and across a period.
Describe and explain the reactions of Group 1 elements with water	Students can describe the observations and explain the reactions of Group 1 elements with water.
Describe and explain the reactions of Group 17 elements with halide ions	Students can describe the observations and explain the reactions of Group 17 elements with halide ions.

Starter ideas

1 Revision of the trend of first ionisation energy across a period (10 minutes)

Resources: An IB past paper question; for example, 2017 November HL Paper 2 Question 3(a).

Description and purpose: Students should attempt the question and then self-assess with the marking scheme, paying attention to keywords.

What to do next: This activity allows students to recall knowledge from Chapter 3. By self-assessing, students can understand the marking schemes better and learn from their mistakes.

› **Language focus:** Students produce clear and well-written explanations using correct keywords.

Main teaching ideas

1 Demonstrations of reactions of the alkali metals (30 minutes)

Resources: Adapt the demonstrations for this from the Royal Society of Chemistry website; search for 'reactions of alkali metals'.

Description and purpose: Students can watch a demonstration or a video of reactions of the alkali metals with air and water. Ask students to explain why the elements all react in similar ways and why there is an increase in reactivity as you go down the group. Students should write out the balanced chemical equations for these reactions.

› **Differentiation ideas:**

Support: Ask students to write down their observations for each reaction of the metals with water, relating their observations to the electron configuration of the alkali metals.

Stretch and challenge: Students can come up with their own explanations for the trend in the reactivity / metallic character of the alkali metals and explain them in front of the class.

2 Periodicity in properties of elements (60 minutes)

Resources: Provide numerical data (from the data booklet) or graphical data (from Figures **10.8**, **10.10**, **10.12**, **10.13**, **10.16**, **10.18**, **10.20** and **10.21** of the Coursebook) on atomic radius, ionic radius, first ionisation energy, electron affinity and electronegativity across a period / down a group.

Description and purpose: Ask students to 1) describe a pattern and 2) provide an explanation (aim for a three-mark answer). For data on Group 17 electron affinity, make sure to emphasise the discontinuity in the trend from F to Cl.

› **Differentiation ideas:**

Support: Students can be put into mixed-ability groups to work collaboratively and learn from their peers. Group work encourages more discussions and allows the teacher to give verbal support accordingly.

› **Assessment ideas:** Students can be provided with marking schemes to assess their answers.

Stretch and challenge: Students can research the difference between covalent radius and Van der Waals radius.

› **Language focus:** Students produce clear descriptions of trends and well-written explanations using the correct keywords.

3 Demonstration / practical on the displacement reactions of halogens (30 minutes)

Resources: Adapt experiments from the Royal Society of Chemistry website for displacement reactions of halogens.

Description and purpose: Ask students to record their observations and write out balanced chemical and ionic equations for all the reactions that occur.

› **Differentiation ideas:**

Support: Provide a detailed step-by-step method and a table to record the results. Ask students to consider the order of reactivity of the halogens from their electron configurations.

Stretch and challenge: Students plan and carry out the experiments on the microscale. Research explanations on the trend in reactivity in Group 17 elements, especially why F_2 is more reactive than Cl_2, despite the less exothermic electron affinity for F.

Plenary ideas

1 Multiple choice questions on the properties of Group 1 and Group 17 elements (5 minutes)

Resources: Past paper questions, for example, 2013 May TZ2 HL Paper 1 Question 7.

Description and purpose: This exercise gives students an opportunity to apply their knowledge and make quick decisions under timed conditions.

› **Assessment ideas:** Provide answers on the board or as handouts.

2 True or false questions to compare properties (5 minutes)

Resources: Test your understanding Question 7 from the Coursebook.

Description and purpose: Students recall their knowledge on the trends of physical properties and they can correct false statements.

10.4 Oxides

LEARNING PLAN

Learning objectives	Success criteria
Describe the trends in the acid–base behaviour of oxides	Students should be able to describe the continuum of metallic and non-metallic properties across a period, including the trend in the acid–base behaviour of oxides.
Write equations for the reactions with water of the oxides of Group 1 and 2 metals, carbon and sulfur	Students can write equations for the reactions with water of the oxides of Group 1 and 2 metals, carbon and sulfur.
Explain acid rain and ocean acidification	Students can explain the causes of acid rain and ocean acidification.

Common misconceptions

Misconceptions	How to identify	How to overcome
Students confuse the group numbers of the p-block elements.	Ask students to assign group numbers to some elements, for example, P, S and Cl.	Pre-IB, when students are introduced to the concept of group number, only the main group elements are included and these elements are assigned group numbers 1 to 8 (or 0).

Misconceptions	How to identify	How to overcome
		This simplified system works well as an introduction to electron configuration, as the number of outer-shell electrons correspond to the group number. In the simplified system, carbon would be in Group 4 and chlorine in Group 7. However, this is not the full picture. In an IB databook, carbon now belongs to Group 14 and chlorine to Group 17. This change happened after a proposal by IUPAC back in 1985. Prior to this, there were other naming systems (for example, the A and B systems) for groups in order to assign a group number to the d-block elements. However, they were somewhat arbitrary rules and confusion arose. The IUPAC proposal to name, for example, the main groups as Groups 13–17 was accepted, and the d-block elements were numbered Groups 3–12 in the middle of the periodic table. However, this system still left out f-block elements, which do not have a group number.

Starter ideas

1 Acid rain formation (10 minutes)

Resources: A picture showing the formation and effects of acid rain, search shutterstock.com for 'acid rain'.

Description and purpose: Ask students to consider how acid rain is formed, recalling pre-IB knowledge. Students can write out balanced symbol equations for the formation of sulfuric(VI) acid and nitric(V) acid in the rain.

What to do next: This activity allows teachers to assess students' prior knowledge on acid rain and how it is formed from non-metal oxides. Teachers can then decide how much depth to go into on acid rain formation in the lesson.

Main teaching ideas

1 Demonstration or practical on the acidic and basic properties of Period 3 oxides (30 minutes)

Resources: Search the Royal Society of Chemistry website for experiments on testing the pH of oxides. Additionally, a teacher can demonstrate burning Mg / S in O_2 then adding water and testing the pH of the resultant solutions.

Description and purpose: These experiments show the idea that soluble metal oxides form alkaline solutions with water, and non-metal oxides form acidic solutions.

› Differentiation ideas:

Support: Students can start with writing out word equations for the reactions of soluble metal or non-metal oxides with water, then convert to symbol equations with the formulas given by teachers.

Stretch and challenge: Students can start by writing balanced symbol equations for the oxides with water, then work out the balanced equations for amphoteric oxides (for example, aluminium oxide) with water / acids / bases.

2 Discussion on ocean acidification (30 minutes)

Resources: Sub-chapter 10.4 of the Coursebook and the internet.

Description and purpose: Students share a fact sheet (e.g., on Google Docs) to answer the following questions on ocean acidification: i) Write an equation to show how CO_2 in the atmosphere and CO_2 in ocean water exist in a heterogeneous equilibrium, including state symbols. ii) Explain the effect of increasing concentrations of atmospheric CO_2 due to anthropogenic activities on the pH of the oceans.

› **Differentiation ideas:**

Support: Students can be assigned to mixed-ability groups. The teacher can help with 1) writing equilibrium equations and applying Le Chatelier's principle, 2) explaining the dissociation of acids in water and 3) showing how pH is related to the concentration of H^+ in solutions.

Stretch and challenge: Students can research further into how the acidity of the ocean can be reduced.

› **Language focus:** Students produce successful fact sheets that explain the answers, including relevant equations.

Plenary ideas

1 Classification of oxides of various elements (10 minutes)

Resources: Test your understanding Question 15 from the Coursebook.

Description and purpose: A quick exercise to assess if students can recognise metal / metalloid / non-metal elements and recall the properties of their oxides. Students can self-assess their answers.

10.5 Oxidation state

LEARNING PLAN

Learning objectives	Success criteria
Deduce oxidation states for elements in molecules and ions	Students can explain what an oxidation state represents.
Name compounds using oxidation states	Students should be able to deduce oxidation states for elements in molecules and ions, including exceptions of metal hydrides and peroxides.
	Students should be able to explain why the oxidation state of an element is zero.
	Students should be able to name compounds using oxidation states.
	Students will understand that, for oxyanions, they can be named using oxidation states but generic names are also accepted.
	Students can interconvert names and formulas of binary ionic compounds.

Common misconceptions

Misconceptions	How to identify	How to overcome
Students confuse oxidation states with charges.	Ask students what the oxidation states for oxygen are in Na_2O and H_2O.	In both cases, the oxidation state for oxygen is −2. As an ion, the oxide ion has a charge of 2−. Charge is written with the number first and then the positive / negative sign. The oxidation state is written with the sign first and then the number. Oxidation states can be assigned to elements in covalent substances when they are not ions.

Starter ideas

1 Definitions of oxidation and reduction (10 minutes)

Resources: A few redox equations on the board, for example:

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

$Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$

Description and purpose: Ask students the meaning of oxidation and reduction in terms of gain or loss of oxygen or electrons. Students should identify which species is oxidised / reduced and which species is the oxidising / reducing agent.

What to do next: Give students a reaction where it is more difficult to identify oxidation / reduction to introduce the concept of oxidation states, for example:

$PCl_3 + Cl_2 \rightarrow PCl_5$

Main teaching ideas

1 Assigning oxidation states (30 minutes)

Resources:

1. Easy: State the oxidation state of nitrogen in the following compounds or ions:
   NH_3, NO, N_2O_4, NO_3^-, N_2F_4, Mg_3N_2.
2. Medium: Give the oxidation state for each element in the following compounds or ions:
   H_3O^+, NaOH, SO_4^{2-}, $Cl_2O_7^-$, OF_2.
3. Hard: Test your understanding Question 20 from the Coursebook plus other examples, including
   Na_2O_2, CH_3COO^-, SCN^-.

Description and purpose: The teacher introduces the concept of oxidation states and explains the rules of assigning oxidation states. Students practice calculating oxidation states with questions of different levels of difficulties.

Differentiation ideas:

Support: Start from the easy level and ask students to assign the oxidation states for O / H / the most electronegative element and then work it out for the other elements. The teacher can give verbal support.

Stretch and challenge: Students can complete the medium and hard questions on their own and self-assess. They can investigate the differences between the concepts of formal charge and oxidation state.

2 Naming compounds / ions using IUPAC rules (30 minutes)

Resources:

1. Easy: NaI, KBr, MgO, $NiCl_2$, $FeCl_2$, $FeCl_3$.
2. Medium: NO, SO_2, SO_3, Cl_2O_7, SeO_2, NO_3^-, NO_2^-, SO_4^{2-}, SO_3^{2-}.
3. Hard: KIO_3, H_3PO_4, $NaNO_3$, HOCl, $NaBrO_3$, NH_4ClO_4.
4. Challenge: $[Fe(H_2O)_6]^{3+}$, $[CuCl_4]^{2-}$, $Pt(NH_3)_2Cl_2$, $[Co(NH_3)_6]^{3+}$.

Description and purpose: The teacher introduces how binary ionic compounds are named using the easy examples, adding in oxidation states for transition element ions. Students then apply the same rules to covalent compounds / ions or more complex ionic compounds. Note: the naming of complex ions (challenge examples) is not required on the IB syllabus.

› **Differentiation ideas:**

Support: Students can work together in groups, starting from the easy and medium level examples. The teacher can support particular groups.

Stretch and challenge: Students can complete the harder questions on their own and self-assess their answers. They can also present their solutions and explain how they worked out the answers to others in class.

Plenary ideas

1 Writing formulas for compounds (10 minutes)

Resources: Give students the names of these chemicals: sulfur(IV) oxide, nitric(V) acid, chloric(III) acid, sodium chromate(VI) and potassium dichromate(VI).

Description and purpose: Students need to recall and apply their knowledge on oxidation states. They can self-assess their answers.

2 Write down a set of guidelines for assigning oxidation states (20 minutes)

Resources: A pen and paper.

Description and purpose: Students are given 10 minutes to write down as many guidelines for assigning oxidation states as they can remember.

› **Assessment ideas:** They then peer-assess each other's answers in pairs using Post-it notes.

› **Language focus:** Recall of knowledge to write some guidelines that someone else can understand.

10.6 Exceptions to the general increase in first ionisation energy across a period and 10.7 The transition elements

LEARNING PLAN

Learning objectives	Success criteria
Explain the exceptions to the increase in first ionisation energy across a period Describe and explain the characteristic properties of transition elements Explain why transition element complexes are coloured Explain the factors that affect the colours of transition element ions	Students can describe and explain the exceptions in the trend of first ionisation energy across a period and how they provide evidence for the existence of energy sublevels. Students know the definition of transition elements. Students can describe and explain the characteristic properties of transition elements, including variable oxidation state, high melting points, magnetic properties, catalytic properties, formation of coloured compounds and formation of complex ions. Students should be able to deduce the electron configuration of first-row transition element ions. Students can explain the formation of coloured transition element complexes. Students can describe and explain the factors that determine the colours of transition element complexes, including the identity of the metal ion, the oxidation state of the metal and the identity of the ligand. Students can interpret the colour wheel to work out the wavelengths and frequencies of light absorbed by transition element complexes.

Common misconceptions

Misconceptions	How to identify	How to overcome
Students confuse the d-block elements and transition metal elements.	Ask students whether Zn is a d-block element or a transition metal element or both.	The d-block elements are elements that have their valence electrons in the d sub-level. Elements in Groups 3–12 in the periodic table are d-block elements. Transition elements have incomplete d sub-levels, so zinc is a d-block element but not a transition element. Zinc also does not have some of the characteristic properties of transition elements, for example, it only has the stable oxidation state of +2 and does not form coloured compounds.

Starter ideas

1 Electron configuration of elements and their ions (20 minutes)

Resources: A mini-whiteboard, pen.

Description and purpose: Students write the electron configurations of some elements, including transition elements and their ions (for example, Be, B, O, N, Fe, Co^{2+}, Cu, Cu^{2+}) on a mini-whiteboard. The teacher should point out the presence of partially filled d sub-shells in the transition elements and some of their ions.

What to do next: This activity allows the teacher to recap knowledge from chapter 3. Some students might need a reminder on the exceptions to the Aufbau principle for Cr and Cu's filling of electrons. Students can draw out the orbital diagrams for the elements and their ions.

› **Assessment ideas:** Use of mini-whiteboards to assess answers and level of understanding.

Main teaching ideas

1 Explaining the exceptions in the trends in first ionisation energy across a period (40 minutes)

Resources: Figure **10.18** in the Coursebook.

Description and purpose: Revision on what first ionisation energy is and why the process of removing electrons from atoms requires energy. Students can discuss in pairs the trends shown in the figure and write out a few bullet-pointed explanations ready to share with the class. Teachers should review the answers and give suggestions on how to improve on the clarity of the explanations.

› **Language focus:** Students produce clear and well-written explanations that others can understand, with key scientific terms.

› **Differentiation ideas:**

Support: For students who find this type of long answer question difficult, they should always be encouraged to write out the full electron configurations of the atoms with sub-levels. Practice until they can confidently identify from which energy level/sub-level an electron is removed. Provide students with model answers on how to explain the trends in first ionisation energy, emphasising key phrases, for example, nuclear charge, shielding, distance between the electrons and the nucleus, repulsion between electrons, and the strength of the electrostatic attraction between the nucleus and the electrons.

Stretch and challenge: Ask students to sketch on graph paper and predict and explain the trends in second ionisation energies of Period 3 elements.

2 Research the properties of transition elements (90 minutes – split this activity into two lessons)

Resources: Sub-chapter 10.7 of the Coursebook and the internet.

Description and purpose: Students need to research the various properties of transition elements, including 1) variable oxidation states; 2) physical properties, including high melting points, conductivity and magnetic properties; 3) catalytic properties; 4) formation of coloured compounds and 5) formation of complex ions with ligands. Specific examples must be given. Students should present summaries of information based on these points:

i Explain why transition elements exhibit variable oxidation states, in contrast to alkali metals.

ii Explain why all 3d transition elements exhibit an oxidation state of +2.

iii Explain why transition elements have high melting points, good conductivity of heat and electricity, and show magnetic properties.

iv Explain what catalysts are, give examples of transition elements and their compounds acting as catalysts, and explain how transition elements can lower the activation energy of reactions.

v Give examples of both neutral and negatively charged ligands. Explain the nature of bonding between transition element ions and ligands in forming complex ions. Examples on working out the oxidation states of transition elements in complex ions. Explain the colour formation by transition element complexes. Give at least two examples of ligand substitution reactions and explain the colour change using Le Chatelier's principle.

› **Language focus:** Students write summaries to clearly explain the properties of transition elements.

› **Differentiation ideas:**

Support: Students can work collaboratively in mixed-ability groups. Each group can be assigned a specific property to do research on. The teacher can give verbal support when needed. For example, when looking at explanations for how transition elements can act as catalysts, the teacher can give students specific examples to investigate, such as the redox reaction between peroxodisulfate ions, $S_2O_8^{2-}$(aq), and iodide ions, I^-(aq), is slow but can be accelerated by Fe^{3+}(aq).

Stretch and challenge: Students can investigate the stereochemistry of transition element complexes, giving examples of geometric and optical isomerism. Students can explain why the second ionisation energy for both Cr and Cu is higher than that of the next element.

3 Colours of transition element complexes (45 minutes)

Resources: A few coloured transition element compounds (iron(II) chloride, iron(III) chloride and sulfate, copper(II) sulfate and carbonate, nickel(II) sulfate, cobalt(II) chloride, etc.) in solution or as solids, a spectrophotometer, a cuvette and 0.1 mol dm^{-3} $CuSO_4$ solution.

Description and purpose: The teacher can demonstrate the visible light spectrum for $CuSO_4$ and discuss the formation of colour. Ask students to list some factors that can affect the colours of the transition element complexes based on the available compounds – the metal present, the oxidation state of the metal, etc.

› **Differentiation ideas:**

Support: Teacher-led discussion on the key points for the explanation of colours (Figure **10.40** in the Coursebook).

Stretch and challenge: Students can investigate the splitting patterns of d orbitals in complexes with different geometries. Very able students should be encouraged to look into crystal field theory and ligand field theory, which are two theories to explain the colours of transition element complexes. They can try to construct an energy level diagram for the octahedral, square planar and tetrahedral geometries.

Plenary ideas

1 A multiple choice question on the characteristic properties of transition elements (5 minutes)

Resources: Which of the following is not a characteristic property of transition elements?

A high melting points
B form complex ions with ligands
C variable oxidation states
D form colourless aqueous solutions

Description and purpose: Students can self-assess their answers and reflect on the learning objective.

2 Explanations for the colours of transition element compounds (10 minutes)

Resources: TiO_2 is used as a pigment in paints. Predict the colour of the pigment and explain your answer.

Description and purpose: Students reflect and explain their knowledge of the colours of the pigment and on the electron configurations of transition element ions.

› **Language focus:** Students can explain their thinking and use correct terms.

Assessment ideas

- Give students a list of different elements and ask them to identify 1) groups, periods and blocks in the periodic table; 2) if they are metals / metalloids / non-metals and 3) the acid–base properties of the oxides of the elements.
- Quiz on the oxidation states of elements for a range of compounds / ions.

- Ask students to name a range of compounds using IUPAC rules.
- Give students incomplete explanations of
  1 trends in physical properties of elements across a period and down a group
  2 colours of transition element complexes; they need to identify the mistakes and correct them.
- Test your understanding questions from the Coursebook.

Homework ideas

- Write a glossary for the keywords from this chapter. An example should be given to show the level of detail required for the definitions.
- Workbook Exercises 10.1–10.7.
- Exam-style questions from the Coursebook.
- Draw a mind map of the physical and chemical properties of Group 1 and Group 17 elements. This can be peer assessed, and students can add to each other's mind map using Post-it notes.
- Search the internet for IB past paper questions on periodicity.
- Students should review the syllabus points and highlight each one with green, yellow or red, depending on how well they understand the content.
- Students can answer questions on how the atomic radius, ionic radius, ionisation energy, electron affinity and electronegativity change across a period and down a group. Their answers will be self-assessed using marking schemes, then the mistakes can be shared and discussed with their peers in small groups.

Links to digital resources

- Elemental sudoku (search the Royal Society of Chemistry website with keywords 'elemental sudoku')
- Periodic table bingo cards (search the internet with keywords 'periodic table, bingo')
- Experiment instruction sheet on the physical properties and chemical reactions of alkali metals (search the Royal Society of Chemistry website for reactions of alkali metals)
- Experiment instruction sheet on the displacement reactions of halogens (search the Royal Society of Chemistry website for displacement reactions of halogens)
- Experiment instruction sheet on testing the pH of the solutions of metal and non-metal oxides (search the Royal Society of Chemistry website for experiments on testing the pH of oxides)
- Past paper questions (search the internet for IB past paper questions on periodicity)
- Summary notes on periodicity (search on ibchem.com for periodicity) (2016 syllabus)
- Extension: Research on superatoms (search the Royal Society of Chemistry website with keywords 'a new kind of alchemy')
- Extra reading: Assigning group numbers in the periodic table (search the internet with keywords 'IUPAC, new notation, group number')

CROSS-CURRICULAR LINKS

- Maths: Interpret graphs, including the significance of changes in gradients.
- Physics: Calculations involving Coulomb's law.
- TOK: The role of imagination and intuition in the sciences. What is the criterion for differentiating science from pseudoscience? Deduction and induction in scientific prediction and reasoning.