7 The covalent model

Teaching plan

Sub-chapter	Approximate number of learning hours	Learning content	Resources
7.1 Covalent bonds 7.2 Shape of molecules: VSEPR theory 7.3 Lone pairs and bond angles 7.4 Multiple bonds and bond angles	3–4	Representation of simple molecules and ions by Lewis formulas (electron dots or Lewis structures) for up to four electron pairs on each atom. Lewis formulas show all the valence electrons (bonding and non-bonding pairs) in a covalently bonded species. The *octet rule* refers to the tendency of atoms to gain a valence shell with a total of eight electrons. Deduction of Lewis structures that follow the octet rule. The valence shell electron-pair repulsion (VSEPR) model enables the shapes of molecules to be predicted from the repulsion of electron domains around a central atom. Prediction of the electron domain geometry and the molecular geometry for species with up to four electron domains.	**Coursebook** Sections 7.1–7.4 Test your understanding Questions 1–11 **Workbook** Exercises 7.1–7.4 **Teacher's resource** PowerPoint 7, slides 2–8 Worksheet 7.1
7.5 Polarity 7.6 Pauling electro-negativities 7.7 Inter-molecular forces 7.8 Melting points and boiling points 7.9 Solubility 7.10 Covalent network structures	3–4	Bond polarity results from the difference in electronegativities of the bonded atoms. Deduction of the polar nature of a covalent bond from electronegativity values. Molecular polarity depends on both bond polarity and molecular geometry. Deduction of the net dipole of a molecule or ion by considering bond polarity and geometry. The nature of the force that exists between molecules is determined by considerations of size and polarity. Intermolecular forces include London (dispersion), dipole–induced dipole, dipole–dipole and hydrogen bonding.	**Coursebook** Sections 7.5–7.10 Test your understanding Questions 12–21 **Workbook** Exercises 7.5–7.10 **Teacher's resource** PowerPoint 7, slides 9–13

Sub-chapter	Approximate number of learning hours	Learning content	Resources
		Deduction of the types of intermolecular force present from the structural features of covalent molecules. Given comparable molar mass, the relative strengths of intermolecular forces are generally London (dispersion) forces < dipole–dipole forces < hydrogen bonding. Chromatography is a technique used to separate the components of a mixture based on their relative attractions involving intermolecular forces to mobile and stationary phases. Carbon and silicon form covalent network structures.	
7.11 The expanded octet 7.12 Formal charge 7.13 Shapes of molecules and ions with an expanded octet 7.14 Hybridisation 7.15 Sigma and pi bonds 7.16 Resonance and delocalisation	3–5	Some atoms can form molecules in which they have an expanded octet of electrons. Formal charge values can be calculated for each atom in a species and used to determine which of several possible Lewis formulas is preferred. Deduction of Lewis formulas and shapes for molecules and ions with expanded octets of electrons. Hybridisation is the concept of mixing atomic orbitals to form new hybrid orbitals for bonding. Sigma bonds form from the head-on overlap of atomic orbitals. Electron density is concentrated along the bond axis. Pi bonds form by the lateral overlap of p orbitals. Electron density is concentrated above and below the bond axis. Resonance structures occur when there is more than one possible position for a double bond in a molecule. Benzene, C_6H_6, is an important example of a molecule that has resonance.	**Coursebook** Sections 7.11–7.16 Test your understanding Questions 22–32 **Workbook** Exercises 7.11–7.16.

BACKGROUND KNOWLEDGE

- Students should have a good understanding of atomic structure.
- Students should be able to work out the number of outer electrons on a non-metal atom from the periodic table.
- Students should have some knowledge of covalent bonding from previous learning either through the MYP programme or GCSE/IGCSE syllabus.

Syllabus overview

- This chapter builds on the students' knowledge of atomic structure to explain covalent bonding in certain molecules. Students will learn how to deduce the structures of certain molecules using the theory taught in this chapter and be able to explain the structure of covalent network structures.
- At Higher Level, students will understand electron delocalisation and apply it to certain structures. They will be able to understand different resonance structures and the formation of s and p bonds. Using this information, they will be able to understand hybridisation and be able to explain the bonding in benzene.

7.1 Covalent bonds; 7.2 Shape of molecules: VSEPR theory; 7.3 Lone pairs and bond angles and 7.4 Multiple bonds and bond angles

LEARNING PLAN

Learning objectives	Success criteria
Explain the term 'covalent bond'	Students can explain the term 'covalent bond'.
Explain the relationship between bond strength and length for multiple bonds	Students can explain the relationship between bond strength and length for multiple bonds.
Explain what a coordination bond is	Students can explain what a coordination bond is.
Deduce Lewis formulas (structures) for covalent molecules	Students can deduce Lewis formulas (structures) for covalent molecules.
Understand what is meant by the 'octet rule'	Students understand what is meant by the 'octet rule'.
Deduce the shapes of molecules / ions with up to four electron domains	Students can deduce the shapes of molecules / ions with up to four electron domains.

Common misconceptions

Misconceptions	How to identify	How to overcome
Students get confused between the different types of bonding.	Exam-style questions will help to identify the misconceptions.	Explain the link between ions and ionic bonding and molecules and covalent bonding. Continuous review and practice questions throughout the year.
Students get confused and think tetrahedral molecules are planar and assign bond angles of 90°.	Seeing how they draw out the shapes of molecules and what bond angles they assign to them.	Highlight the 3D nature of molecules and get them to draw the molecules three-dimensionally.
Students don't realise the lone pairs count as an electron domain.	Seeing how they draw out the shapes of molecules and what bond angles they assign to them.	Make sure that students draw all of the pairs of electrons for structures.

Starter ideas

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

Resources: Students are provided with examples of ionic and covalent compounds and are asked to identify which ones are which.

Description and purpose: Students will use their knowledge from Chapter 6 and what they have learned from pre-IB about covalent bonding.

What to do next: Students can make a mind map of what they already know about covalent bonding.

› **Assessment ideas:** This can be peer assessed with other students adding to it or correcting it.

› **Language focus:** Within the mind map, students should use key scientific terminology and definitions to reinforce their understanding of the topic and language needed

2 Demonstrate bond angles and shapes of molecules (20 minutes)

Resources: Modelling balloons

Description and purpose: The teacher demonstrates using the modelling balloons and the bond angles for species with four, three and two negative charge centres on the central atom using VSEPR.

What to do next: Students can use a visualisation tool, such as PhET, to help them see the shapes and bond angles of molecules.

Main teaching ideas

1 Explanation of covalent and coordinate bonds (30 minutes)

Resources: Diagrams and models of different covalent bonds, including multiple covalent bonds. Molecular modelling kits could be used.

Description and purpose: This exercise gives students visual models to show how a covalent bond is formed. The teacher should explain what a covalent bond is and how a covalent bond is formed. Coordinate bonds should be shown, as well as double and triple bonds.

› **Differentiation ideas**

Support: Students could be given some simple covalent molecules, such as HCl, H_2 and Cl_2, to work out the bonding present using dot and cross diagrams.

Stretch and challenge: Students can be given more complicated molecules with multiple bonds, namely, double and triple bonds, and they can try to work out the dot and cross structures.

2 Work out bond angles and shapes of molecules (30 minutes)

Resources: Worksheet 7.1, with different molecules.

Description and purpose: Students use VSEPR theory to predict the shapes and bond angles of molecules and ions having four pairs of electrons (charge centres) around the central atom. Suitable examples are NH_3, H_2O and alkanes (e.g., CH_4).

Differentiation ideas

Support: Students are given some easy species to predict the shapes and bond angles.

Stretch and challenge: More complex species are given to the students.

3 Matchstick models (30 minutes)

Resources: Matchsticks

Description and purpose: Students are given elements and molecules and are asked to use matchsticks to work out Lewis structures for nitrogen oxides, O_3, CO, etc. Each matchstick represents a pair of electrons.

Differentiation ideas

Support: The students can be grouped and work on different molecules. The teacher can support those groups that need the most help. Students could be paired together so that one student can support another.

Stretch and challenge: More challenging molecules could be given to the students.

Plenary ideas

1 Exit tickets (10 minutes)

Resources: A sheet with the following two questions: What did you learn in the lesson today? Is there anything you need to go over again?

Description and purpose

Reflection: This exercise gives students an opportunity to reflect on their learning from the lesson and give them an opportunity to ask for help with any of the content taught.

7.5 Polarity; 7.6 Pauling electronegativities; 7.7 Intermolecular forces; 7.8 Melting points and boiling points; 7.9 Solubility and 7.10 Covalent network structures

LEARNING PLAN

Learning objectives	Success criteria
Understand what makes a molecule polar	Students understand what makes a molecule polar.
Explain the formation of intermolecular forces	Students can explain the formation of intermolecular forces.
Explain the influence of intermolecular forces on the melting / boiling point of covalent substances	Students can explain the influence of intermolecular forces on the melting / boiling point of covalent substances.
Explain the physical properties of covalent substances	Students can explain the physical properties of covalent substances.

LEARNING PLAN

Explain how mixtures can be separated using paper chromatography and thin-layer chromatography	Students can explain how mixtures can be separated using paper chromatography and thin-layer chromatography.
Describe and explain the bonding and structure of substances with covalent network structures	Students can describe and explain the bonding and structure of substances with covalent network structures.

Common misconceptions

Misconceptions	How to identify	How to overcome
Students get confused between intermolecular forces and covalent bonds.	Descriptions of bonding in molecules in class and homework.	Highlight that intermolecular forces are between molecules, whereas covalent bonds are between atoms.
Students sometimes think certain molecules have hydrogen bonding because when they are written out the hydrogen is next to the oxygen, e.g., CH_3CHO or CH_3F.	Questions testing this information will help to gather knowledge on the students understanding.	Students need to draw out the molecules, so they can see where the bonds are.

Starter ideas

1 Recap the structures of some molecules (e.g., H_2O, CH_4, CH_3CHO) (15 minutes)

Resources: Melting point and boiling point data for some molecules.

Description and purpose: Students recap different molecules, some with lone pairs, some non-polar and some with hydrogen bonding. Discussion between teacher and students about what the differences between these are. Teachers can show boiling points and melting points for different molecules and ask students to think about why they are different.

What to do next: Give students some other molecules and ask them which ones they think will have higher boiling points.

Main teaching ideas

1 Intermolecular forces (30 minutes)

Resources: Electronegativity data for elements.

Description and purpose: Give students different organic molecules with different functional groups and electronegativity data (from data booklet). Students should draw the shapes of these molecules and then work out if the bonds are polar or not and if the overall molecule is polar or not. They can then assign the intermolecular forces to the different molecules (London forces, permanent dipole–permanent dipole interactions, hydrogen bonding).

Differentiation ideas

Support: Give easy examples to work through (CO_2, CH_4, CH_3F, CH_3OH). Students draw out the molecule and work out if the bonds are polar. Then, using the shape, they can work out what intermolecular forces the molecule has.

Stretch and challenge: Give the students more complex and challenging molecules: ethers, esters, carboxylic acids, etc.

2 Importance of hydrogen bonding (45 minutes)

Resources: Computer room or tablets.

Description and purpose: Students research the importance of hydrogen bonding and then present their findings to the rest of the class. Topics they could look at include ice, DNA and solubility.

Differentiation ideas

Support: Students could be given questions to answer to help them research this area.

Stretch and challenge: Students can stretch and challenge themselves by delving deeper into the research and follow up their own areas of interest within the subject matter.

Plenary ideas

1 Show in front of class (10 minutes)

Resources: Whiteboard / interactive whiteboard.

Description and purpose: Students come up to the board and have to draw out the shapes of different molecules and explain the different intermolecular forces these molecules will have.

Assessment ideas: They can be assessed by their peers and corrections can be made. This will help to improve the students' understanding of the topic.

7.11 The expanded octet; 7.12 Formal charge; 7.13 Shapes of molecules and ions with an expanded octet; 7.14 Hybridisation; 7.15 Sigma and pi bonds and 7.16 Resonance and delocalisation

LEARNING PLAN

Learning objectives	Success criteria
Explain resonance and delocalisation of electrons	Students can explain resonance and delocalisation of electrons.
Deduce Lewis formulas and shapes for molecules and ions with expanded octets of electrons	Students can deduce Lewis formulas and shapes for molecules and ions with expanded octets of electrons.
Use formal charge to distinguish between possible Lewis formulas	Students can use formal charge to distinguish between possible Lewis formulas.
Explain the formation of sigma and pi bonds	Students can explain the formation of sigma and pi bonds.
Explain hybridisation	Students can explain hybridisation.
Describe and explain the structure of benzene	Students can describe and explain the structure of benzene.

Common misconceptions

Misconceptions	How to identify	How to overcome
Students forget that Period 3 elements can have an expanded octet.	Give students different molecules and ask them to draw them. Ask students to go through the rules when drawing the shape of a molecule.	Lots of practice with molecules that can have an expanded octet.
Students get confused with what sp^3, sp^2, and sp^1 mean and what are sigma bonds and what are pi bonds.	Questions about hybridisation and bonding in ethane, ethene and ethyne will help to see which students have a full understanding of the content.	Clear explanation of how hybridisation occurs and what types of bonds are formed required. Testing of this regularly will help with understanding.

Starter ideas

1 Molecules with an expanded octet (20 minutes)

Description and purpose: Students are given the formula of a molecule with an expanded octet and asked to deduce and draw a structure for it. Students may find this challenging, as it may not fit in with the rules they have learned previously. Students and the teacher should have a discussion about these molecules and how and why they occur, explaining the empty d shell that can take electrons.

What to do next: Give students some other molecules and ask them to draw out their structures and say which ones have an expanded octet.

Main teaching ideas

1 s and p orbital formation (30 minutes)

Resources: Models and diagrams of benzene or another delocalised molecules.

Description and purpose: The teacher explains the theory behind s and p orbitals using the models to help students visualise the different orbitals and how they interact in a molecule. Students can see the s orbitals overlapping head on and the p orbitals overlapping side on.

› Differentiation ideas

Support: Students are asked to draw out the orbitals of ethene and label the s and p orbitals. They can be given questions asking how many s and p orbitals are in some simple molecules.

Stretch and challenge: Students can be given more complicated molecules and asked to work out how many s and p orbitals are present.

2 Hybridisation (40 minutes)

Resources: Hybridisation, sigma and pi bonds modelling kit.

Description and purpose: Students are shown the s and p orbitals and talked through how hybridisation occurs. They can then use the modelling kits to show sigma and pi bonding in different molecules.

› Differentiation ideas

Support: The teacher talks about a simple model that the students can see to show the different sigma and pi bonding present in the molecule.

Stretch and challenge: Students could try to build their own model of benzene showing hybridisation and delocalisation.

3 Formal charge (40 minutes)

Resources: mini whiteboards

Description and purpose: Students are asked to draw out 2 different Lewis structure for SO_2. The teacher then explains how to work out formal charge to show which would be the preferred Lewis structure.

Differentiation ideas

Support: Students could be given a step by step method to work out the Lewis structure and then the formal charge

Stretch and challenge: Students could try to other molecules such as SO_4^{2-} or $POCl_3$

Plenary ideas

1 Reflection on this chapter (25 minutes)

Resources: Mind map with leading questions could be provided.

Description and purpose: Students make a mind map revision sheet for this chapter, highlighting the key concepts that they need to know. This will help to reinforce their knowledge of the content. For students who are struggling, a mind map that has headings and some leading questions could be used to help them.

Language focus: The teacher could give a list of key definitions to the students to help with their understanding.

Assessment ideas

- Test on both ionic and covalent bonding will be useful, as the teacher would be able to see if students are getting confused between the two different types of bonding and could then identify the misconceptions.
- Build on the mind map from the plenary ideas and get students to read through other students' work and add to it. These could also be marked to elicit whether every student has a full understanding of the content in this chapter.

Homework ideas

- Students make their own flashcards on the different intermolecular forces or different shapes of molecules.
- Write a quizlet for this chapter, or sub-section of the chapter, and then the students can provide answers.
- Provide a list of different covalent molecules, and the students work out shapes and bond angles for them using VSEPR theory.
- Using their own flash cards or ready-made ones (Smart prep cards are professionally done), students can go through the content and reflect on their learning. They can make a list of the syllabus points that they are unsure of and revisit these to make sure they have a secure understanding of the content.

Links to digital resources

- Model molecules showing the shapes and how lone pairs of electrons affect the shapes and bond angles
- Notes on covalent bonding, shapes of molecules, polarity, intermolecular forces, metallic bonding and ionic bonding

CROSS-CURRICULAR LINKS

- ICT: Model bond angles and shapes of molecules.
- TOK: How theories are formed and tested and built upon.