

# > 22 Electron-pair sharing reactions

## Teaching plan

Sub-chapter	Approximate number of learning hours	Learning content	Resources
22.1 Nucleophilic substitution reactions 22.2 Addition reactions	3–4	<p>Definition of a nucleophile and recognise nucleophiles in chemical reactions.</p> <p>Writing equations of nucleophilic substitution reactions using curly arrows.</p> <p>Compare heterolytic fission with homolytic fission and explain the formation of ions by heterolytic fissions.</p> <p>Definition of an electrophile and recognise electrophiles in chemical reactions.</p> <p>Writing equations of electrophilic addition reactions.</p> <p>Explain why alkenes undergo electrophilic additions.</p>	<p><b>Coursebook</b></p> <p>Sections 22.1–22.2</p> <p>Test your understanding Questions 1–3 and 5</p> <p><b>Workbook</b></p> <p>Exercises 22.1–22.2</p> <p><b>Teacher's resource</b></p> <p>↓ PowerPoint 22, slides 2–5</p> <p>↓ Worksheet 22.1 Question 2</p> <p>↓ End of Chapter 22 test Questions 5, 10 and 12</p>
22.3 Lewis acids and bases	2	<p>Definition of Lewis acids / bases.</p> <p>Explain the formation of a coordinate bond.</p> <p>Identify Lewis acids / bases in organic and inorganic reactions.</p> <p>Explain the formation of complex ions and deduce their charges.</p>	<p><b>Coursebook</b></p> <p>Section 22.3</p> <p>Test your understanding Questions 9–10</p> <p><b>Workbook</b></p> <p>Exercise 22.3</p> <p><b>Teacher's resource</b></p> <p>↓ PowerPoint 22, slides 6–8</p> <p>↓ Worksheet 22.1 Question 1</p> <p>↓ End of Chapter 22 test Questions 1, 3–4</p>

Sub-chapter	Approximate number of learning hours	Learning content	Resources
22.4 Nucleophilic substitution mechanisms	2	<p>Explain the mechanism of nucleophilic substitution.</p> <p>Know the difference between <math>S_N1</math> and <math>S_N2</math> reactions and the stereospecific nature of <math>S_N2</math> reactions.</p> <p>Explain how different halides affect the rates of nucleophilic substitution reactions of halogenoalkanes.</p>	<p><b>Coursebook</b></p> <p>Section 22.4</p> <p>Test your understanding Question 15</p> <p><b>Workbook</b></p> <p>Exercise 22.4</p> <p><b>Teacher's resource</b></p> <p>↓ PowerPoint 22, slides 9–11</p> <p>↓ Worksheet 22.1 Question 3</p> <p>↓ End of Chapter 22 test Question 2</p>
22.5 Electrophilic addition reactions of alkenes	2	<p>Explain the mechanism of electrophilic addition.</p> <p>Predict and explain the major and minor products of the addition reaction of an unsymmetrical alkene.</p>	<p><b>Coursebook</b></p> <p>Section 22.5</p> <p>Test your understanding Question 20</p> <p><b>Workbook</b></p> <p>Exercise 22.5</p> <p><b>Teacher's resource</b></p> <p>↓ PowerPoint 22, slides 12–14</p> <p>↓ Worksheet 22.1 Question 3</p> <p>↓ End of Chapter 22 test Questions 6–7</p>
22.6 Electrophilic substitution reactions	1–2	<p>Explain the mechanism of electrophilic substitution of benzene.</p>	<p><b>Coursebook</b></p> <p>Section 22.6</p> <p><b>Workbook</b></p> <p>Exercise 22.6</p> <p><b>Teacher's resource</b></p> <p>↓ PowerPoint 22, slides 15–16</p> <p>↓ Worksheet 22.1 Question 2</p> <p>↓ End of Chapter 22 test Questions 8–9 and 11</p>

### BACKGROUND KNOWLEDGE

- Recall the Brønsted–Lowry theory of acids and bases and know how to identify them in reactions (Chapter 19).
- Explain what complex ions are and identify the ligands (Chapter 10).
- Describe the features of the benzene resonance structure (Chapter 7).
- Recall functional groups and identify primary, secondary and tertiary halogenoalkanes (Chapter 11).
- Describe the use of single-barbed (fish-hook) arrows in the homolytic fission mechanism (Chapter 21).

## Syllabus overview

- Continuing from Chapter 21, more reaction mechanisms are introduced in this chapter, involving heterolytic fissions and, therefore, the formation of charged species in reactions. At Standard Level, students should be able to explain electron movements in the nucleophilic substitution reactions of halogenoalkanes; construct equations for electrophilic additions of alkenes; and explain the meanings of nucleophiles, electrophiles and heterolytic fission.
- The Lewis acid–base definition is introduced at Higher Level. Lewis theory includes all the acids and bases defined by Brønsted–Lowry theory (Chapter 19), for example, a proton acceptor (Brønsted–Lowry base) uses a pair of electrons to form a coordination bond with a proton and is, therefore, a Lewis base. However, it expands the range of acids and bases to include those that do not contain protons. A transition element, or its ions, acts as a Lewis acid in complex ions, and a nucleophile / electrophile in organic reactions is equivalent to a Lewis base / acid. Students will then explore the factors affecting the rates of nucleophilic substitutions, and the detailed mechanisms of electrophilic addition and electrophilic substitution reactions.

## 22.1 Nucleophilic substitution reactions and 22.2 Addition reactions

### LEARNING PLAN

Learning objectives	Success criteria
Understand the term nucleophile	Students can explain what nucleophiles are and give examples for them.
Describe nucleophilic substitution reactions	Students can write equations and draw mechanisms to show the movement of electron pairs in nucleophilic substitution reactions.
Understand the term heterolytic fission	Students can explain with curly arrows the movement of electrons in heterolytic fission.
Understand the term electrophile	Students can explain what electrophiles are and give examples of them.
Understand why alkenes are more reactive than alkanes	Students can construct equations for the electrophilic addition of alkenes and explain why alkenes are more reactive than alkanes.
Construct equations for the reaction of alkenes	

## Common misconceptions

Misconceptions	How to identify	How to overcome
Students think that alkanes are more reactive than alkenes because double bonds are stronger than single bonds.	Ask students to explain why alkenes can decolorise bromine water in the dark, whereas alkanes can only do so in the presence of UV light / sunlight.	When alkene reacts through electrophilic addition, only the $\pi$ bond of the double bond breaks. The C—C $\pi$ bond is weaker than the C—C $\sigma$ bond; therefore, it takes less activation energy for alkenes to react with halogens via electrophilic addition than for alkanes to react with halogens via free radical substitution.

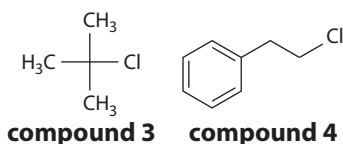
## Starter ideas

### 1 Primary, secondary and tertiary halogenoalkanes (10 minutes)

**Resources:** Names or formulas of halogenoalkanes, for example:

**compound 1** 2-bromobutane

**compound 2** 2-iodo-3,3-dimethylpentane



**Description and purpose:** Students identify primary, secondary and tertiary halogenoalkanes.

**What to do next:** Students recall knowledge from Chapter 11 and explain how to classify the halogenoalkanes.

## Main teaching ideas

### 1 Hydrolysis of halogenoalkanes (60 minutes)

**Resources:** Chemicals and equipment required for demonstrating the  $S_N2$  reactions of chloroalkanes. A protocol can be found by searching for 'nucleophilic substitution reactions', 'sn1 vs sn2', 'lab report' on the internet.

**Description and purpose:** The teacher demonstrates the nucleophilic substitution of chloroalkanes using NaI / acetone as the nucleophile / solvent combination (which favours  $S_N2$  reactions). Students research using either the Coursebook or the internet to explain the nucleophilic substitution reactions of halogenoalkanes, using the alkaline hydrolysis reaction as an example.

#### › Differentiation ideas:

**Support:** The teacher goes through the mechanisms with students and shows animations (many can be found online by searching the internet with the keywords 'animation' and 'nucleophilic substitution mechanism'). Emphasise how the curly arrows show that the electron pair moves from the nucleophile to form a coordination bond with the  $\delta^+$  C atom bonded to the halogen and another pair of electrons moves to the halogen to produce the halide ion.

**Stretch and challenge:** Students present and explain the  $S_N2$  mechanism to the class with information on the nucleophile, coordination bond, leaving group, heterolytic fission and curly arrows.

## 2 Other examples of nucleophilic substitution reactions (30 minutes)

**Resources:** Test your understanding Question 1 from the Coursebook, pen and paper.

**Description and purpose:** Students deduce the products from the substitution of halogenoalkanes with a range of different nucleophiles and identify the functional groups in the organic products. This shows students how functional groups can be converted.

### > Differentiation ideas:

**Support:** Students can be assigned to mixed-ability groups and work collaboratively.

**Stretch and challenge:** Students can deduce the mechanisms of  $S_N2$  reactions using  $CN^-$  and  $NH_3$  as nucleophiles.

> **Assessment ideas:** Molecular models can be used to identify the correct structures of the products.

## 3 Electrophilic addition reactions of alkenes (60 minutes)

**Resources:** Cyclohexene, bromine water, a boiling tube, and Test your understanding Questions 2, 3 and 5:

- 1 easy: Test your understanding Question 2
- 2 medium: Test your understanding Question 3
- 3 hard: Test your understanding Question 5.

**Description and purpose:** The teacher introduces the electrophilic addition reaction of alkenes by demonstrating with cyclohexene and bromine water and discussing the equation for the reaction. Students can work out the meaning of electrophiles based on what they have learned about nucleophiles. The teacher points out that the high electron density of the  $C=C$  double bond attracts the electrophiles and asks students to give some examples of electrophiles.

### > Differentiation ideas:

**Support:** Give students the choice to start the exercise from different levels, and the teacher can provide support accordingly.

**Stretch and challenge:** Students can look ahead and research into the mechanisms for these reactions and how to determine the major and minor products when addition happens across unsymmetrical alkenes.

## Plenary ideas

### 1 Identify the nucleophiles and electrophiles from the following groups of molecules and ions (15 minutes)

**Resources:** A list of molecules / ions, for example:  $OH^-$ ,  $Cl^-$ ,  $Cl_2$ ,  $HCl$ ,  $H_2O$ ,  $CN^-$ ,  $NH_3$ .

**Description and purpose:** Students can self-assess their answers and explain to their peers the meanings of nucleophiles and electrophiles. Note some species can act as both nucleophile and electrophile, depending on the reactions.

### 2 Nucleophilic substitution mechanism (15 minutes)

**Resources:** The nucleophilic substitution reaction mechanism card, which can be downloaded from the Royal Society of Chemistry website.

**Description and purpose:** Students can work in pairs to construct the mechanism of the nucleophilic substitution of bromoethane with  $OH^-$ .

## 22.3 Lewis acids and bases

### LEARNING PLAN

#### Learning objectives

- Understand the Lewis definition of acids and bases

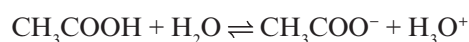
#### Success criteria

Students can explain what Lewis acids / bases are and identify them in both organic and inorganic reactions.

### Starter ideas

#### 1 Conjugate acid–base pair (10 minutes)

**Resources:** A mini-whiteboard, pens, some examples of acid–base reactions, for example:



**Description and purpose:** Students identify two conjugate acid–base pairs in the reaction.

**What to do next:** Ask students to show how water can accept the proton from ethanoic acid using curly arrows and explain the movement of electron pairs.

### Main teaching ideas

#### 1 Lewis acid and base theory (40 minutes)

**Resources:** Examples of Lewis acid–base reactions, for example, Test your understanding Questions 9 and 10 from the Coursebook.

**Description and purpose:** The teacher leads the discussion on how Brønsted–Lowry bases use a lone pair of electrons to form coordination bonds with protons and introduces the Lewis acid–base definitions. Relate to organic reactions discussed in sub-chapters 22.1 and 22.2 that nucleophiles are Lewis bases and electrophiles are Lewis acids. Students then attempt Test your understanding Questions 9 and 10.

##### › Differentiation ideas:

**Support:** The teacher can support students by showing the lone pair of electrons on Lewis bases and show the formation of the coordination bond with Lewis acids in reactions using curly arrows.

**Stretch and challenge:** Students can compare the Arrhenius, Brønsted–Lowry and Lewis acid–base definitions and present a summary to the rest of the class, including discussions on why Lewis acid–base theory encompasses a wider range of reactions.

#### 2 Complex ion ligand substitution reactions (40 minutes)

**Resources:** Concentrated HCl, concentrated  $\text{NH}_3$ ,  $\text{CuSO}_4$  solution, dilute  $\text{NH}_3$ ,  $\text{CrCl}_3$  solution.

**Description and purpose:** The teacher demonstrates a few examples of ligand substitution reactions, for example: from  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$  to  $[\text{CuCl}_4]^{2-}(\text{aq})$ , from  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$  to  $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}(\text{aq})$  and  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$  to  $[\text{Cr}(\text{NH}_3)_6]^{3+}(\text{aq})$ . Students can identify the ligands and the oxidation state of the transition element ion in each complex ion. This activity also provides opportunities to revise knowledge from Chapter 10 on the colour of transition element complex ions.

##### › Differentiation ideas:

**Support:** Students can be assigned to mixed-ability groups and work collaboratively.

**Stretch and challenge:** Students can draw out the shapes of the complex ions, showing coordination bond formation between the ligands and the metal ions. They can also find other examples of Lewis acid–base reactions that are not defined by Brønsted–Lowry theory.

## Plenary ideas

### 1 A multiple choice question on Lewis acid–base theory (5 minutes)

**Resources:** Past paper question, for example, question 28 on May 2016 TZ0 paper 1.

**Description and purpose:** Students need to apply their knowledge and make a quick decision under timed conditions.

### 2 Classification of substances according to Lewis acid–base theory (10 minutes)

**Resources:** A list of substances, such as  $\text{OH}^-$ ,  $\text{CN}^-$ ,  $\text{Fe}^{3+}$ ,  $\text{BH}_3$ ,  $\text{BH}_4^-$ ,  $\text{CH}_3\text{Cl}$ .

**Description and purpose:** Students can work in pairs to identify the Lewis acids and Lewis bases from this list and explain the reasoning to their peers.

## 22.4 Nucleophilic substitution mechanisms

### LEARNING PLAN

#### Learning objectives

- > Understand the mechanism for nucleophilic substitution reactions
- > Explain how the nature of the leaving group affects the rate of nucleophilic substitution reactions

#### Success criteria

Students can describe and explain the nucleophilic substitution mechanisms, distinguishing between  $\text{S}_{\text{N}}1$  and  $\text{S}_{\text{N}}2$ .

Students can predict and explain the relative rates of nucleophilic substitution for different halogenoalkanes.

## Common misconceptions

Misconceptions	How to identify	How to overcome
Students think that the relative rates of halogenoalkanes in nucleophilic substitution are due to the electronegativity of the halogens.	Ask students to predict the rates of alkaline hydrolysis of $\text{R}-\text{Cl}$ vs $\text{R}-\text{Br}$ vs $\text{R}-\text{I}$ . Some students think the order is $\text{R}-\text{Cl} > \text{R}-\text{Br} > \text{R}-\text{I}$ because Cl is the most electronegative halogen in these reactions.	Teachers can demonstrate the alkaline hydrolysis of a few halogenoalkanes, for example, 1-chlorobutane vs 1-bromobutane vs 1-iodobutane. The iodo compound reacts faster than the bromo one, which, in turn, reacts faster than the chloro compound. This is due to the bond enthalpy of the C–halogen bond. The bigger the halogen atom, the further the shared pair of electrons in the C–halogen covalent bond is from the nuclei of the atoms, so the weaker the C–halogen bond.

Misconceptions	How to identify	How to overcome
Students assume that $S_N2$ is always faster than $S_N1$ , as there are two steps in $S_N1$ and only one step in $S_N2$ .	Ask students to predict the rates of alkaline hydrolysis of 1-chlorobutane vs 2-chloro-2-methylpropane at room temperature.	It is difficult to compare the rates of these two mechanisms directly, as primary halogenoalkanes are more likely to undergo $S_N2$ and tertiary halogenoalkanes are more likely to undergo $S_N1$ . $S_N2$ occurs in a single step, but this does not necessarily mean that it is faster than the two-step $S_N1$ , as the tertiary carbocation formed in a $S_N1$ mechanism of a tertiary halogenoalkane is stabilised, so the rate-determining step can be fast in a $S_N1$ reaction. The rates of the reactions are also affected by the leaving groups, the nucleophiles present and the solvents used.

## Starter ideas

### 1 Recap on the $S_N2$ mechanism covered at Standard Level (10 minutes)

**Resources:** A mini-whiteboard and pens.

**Description and purpose:** Students draw the mechanism for the reaction of chloromethane with  $\text{OH}^-$ , consolidating knowledge from sub-chapter 22.1.

**What to do next:** The teacher explains that the  $S_N1$  mechanism can also occur for other nucleophilic substitutions, and the choice of mechanism depends on the types of halogenoalkanes, the nucleophiles and the solvents used.

## Main teaching ideas

### 1 $S_N1$ and $S_N2$ mechanisms (50 minutes)

**Resources:** Search the internet with the keywords 'University of Surrey', ' $S_N1$ ' and ' $S_N2$ ' for animations showing  $S_N1$  and  $S_N2$  mechanisms. Molecular models.

**Description and purpose:** The teacher shows animations of  $S_N1$  and  $S_N2$  mechanisms and explains the movements of electrons and the reaction profiles for the two different mechanisms. Students can use molecular models to visualise attack of the halogenoalkanes by the nucleophiles and the difference in stereochemistry for the two different mechanisms. Students practice drawing mechanisms for both  $S_N1$  and  $S_N2$  reactions of tertiary and primary halogenoalkanes.

#### > Differentiation ideas:

**Support:** Group students by ability and give them the choice of either drawing the mechanisms step by step with the teacher or drawing and self-assessing their answers with the Coursebook.

**Stretch and challenge:** Students research why  $S_N2$  is more favourable for primary halogenoalkanes and  $S_N1$  is more favourable for tertiary halogenoalkanes and present their information to the class. Use Coursebook sub-chapter 22.4 or search for more information on Chemguide.

### 2 Rates of nucleophilic substitution (45 minutes)

**Resources:** If available, 1-chlorobutane, 1-bromobutane and 1-iodobutane as the halogenoalkanes; NaI solid; acetone; and a water bath at 60 °C. A protocol can be found on the internet. Search using the words 'experiment 8 relative rates of nucleophilic substitution'.



**Description and purpose:** The teacher demonstrates the  $S_N2$  nucleophilic substitution of primary halogenoalkanes using NaI / acetone as the nucleophile / solvent combination to favour  $S_N2$  reactions. A trend should be observed that the iodoalkane reacts faster than the bromoalkane, which, in turn, reacts faster than the chloroalkane.

› **Differentiation ideas:**

**Support:** Teacher-led discussion of the explanation for the relative rates of substitution reactions of different halogenoalkanes.

**Stretch and challenge:** Students can research the solvent effect and find out which sets of conditions can be used to favour either  $S_N1$  or  $S_N2$  in practicals and why.

## Plenary ideas

### 1 Inversion of stereochemistry in $S_N2$ reactions (5 minutes)

**Resources:** Test your understanding Question 15 from the Coursebook.

**Description and purpose:** The  $S_N2$  reaction occurs with inversion of configuration at the chiral centre. Students can practice drawing stereoisomers in 3D and peer assess each other's answers.

### 2 A multiple choice question on synthetic pathways (5 minutes)

**Resources:** What is the correct order of reaction types in the following reaction sequence?



- A oxidation → substitution → condensation
- B substitution → oxidation → condensation
- C substitution → oxidation → reduction
- D oxidation → oxidation → reduction

**Description and purpose:** Consolidate students' knowledge of the conversion of functional groups. They can also give the reaction conditions and reagents required for each step. The correct answer is B.

## 22.5 Electrophilic addition reactions of alkenes

### LEARNING PLAN

#### Learning objectives

- › Understand the mechanism for electrophilic addition reactions
- › Understand the reactions of unsymmetrical alkenes with hydrogen halides

#### Success criteria

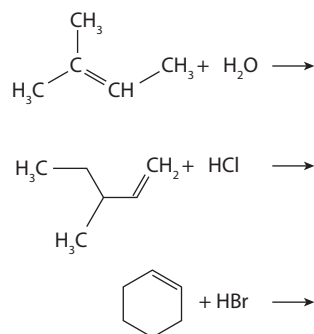
Students can write equations and draw mechanisms to show the movement of electron pairs in electrophilic addition reactions.

Students can predict and explain the formation of major / minor products in the reactions of unsymmetrical alkenes with halogen halides.

## Starter ideas

### 1 Addition reactions of alkenes (10 minutes)

**Resources:** A list of incomplete reactions, for example:



**Description and purpose:** Students work out the products for the reactions and identify where more than one product is possible.

**What to do next:** Discuss why alkenes are more reactive than alkanes and how alkenes can attract electrophiles. Revise the definition of an electrophile.

## Main teaching ideas

### 1 Electrophilic addition mechanism (30 minutes)

**Resources:** Search the Royal Society of Chemistry website with the keywords 'mechanism inspector'. On the webpage, go to *Study the background science* and click on *Electrophilic addition*.

**Description and purpose:** There is an introduction to the electrophilic addition mechanism on the webpage, which summarises different types of substances that can be added across the C=C bond in alkenes. Students need to answer questions about the mechanism correctly before moving onto the next stage of the quiz. Students then draw out an electrophilic addition mechanism themselves.

#### > Differentiation ideas:

**Support:** Students work in pairs for the online quiz and teachers support accordingly. The teacher can also provide filling the gap exercises for students to annotate the mechanism.

**Stretch and challenge:** Students complete the online quiz on the Royal Society of Chemistry's mechanism inspector independently and draw out the mechanism for, for example, HCl adding to propene independently.

### 2 Markovnikov's rule (45 minutes)

**Resources:** Search the Royal Society of Chemistry website with the keywords 'mechanism inspector'. On the webpage, go to *Study the background science* and click on *Carbocations*.

**Description and purpose:** Students should know what carbocation intermediates are from the study of the S<sub>N</sub>1 mechanism and know that, for unsymmetrical alkenes, more than one addition product can be formed. Use the Royal Society of Chemistry animation to explain the relative stability of different carbocation intermediates and how this leads to the formation of major / minor products.

#### > Differentiation ideas:

**Support:** Students practice drawing the mechanism with but-1-ene and HBr and use Markovnikov's rule to predict the major product.

**Stretch and challenge:** The teacher explains the formation of the major product using but-1-ene and ICl, showing possible carbocation intermediates and commenting on their relative stabilities.

## Plenary ideas

### 1 Predict the more stable carbocation in electrophilic additions (10 minutes)

**Resources** Test your understanding Question 20 from the Coursebook.

**Description and purpose:** Students can self-assess their answers.

### 2 Summarise how to identify the major products in electrophilic additions (10 minutes)

**Resources:** Pen and paper.

**Description and purpose:** Students are given 5 minutes to write down the processes for determining the major products in electrophilic additions, including explanations on carbocation intermediates and the positive inductive / electron-releasing effects of alkyl groups.

› **Language focus:** Well-written explanations of the processes, including a good level of detail and the correct terms.

## 22.6 Electrophilic substitution reactions

### LEARNING PLAN

#### Learning objectives

- › Understand the mechanism for electrophilic substitution reactions

#### Success criteria

Students can draw mechanisms to show the movement of electron pairs in electrophilic substitution reactions of benzene.

## Common misconceptions

Misconceptions	How to identify	How to overcome
Students think that benzene is not saturated, so it favours addition reactions.	Ask students to name the type of reaction benzene undergoes with bromine.	Benzene can take part in addition reactions, for example, hydrogenation. However, this involves breaking the $\pi$ system of the delocalised electrons and, therefore, requires a large amount of activation energy. Benzene undergoes mainly an electrophilic substitution reaction, for example, its nitration or reaction with bromine. The teacher can show a video of benzene only decolorising bromine water in the presence of a catalyst and explain that this is different from the reaction of bromine water with unsaturated alkenes.

## Starter ideas

### 1 Benzene's structure (15 minutes)

**Resources:** A mini-whiteboard and pens.

**Description and purpose:** Ask students to describe the structure of benzene and to provide at least two pieces of evidence that support the delocalised structure.

**What to do next:** If students find it difficult to recall the evidence, they should use Chapter 7 to consolidate. Students need to be confident with explaining the stability of the delocalised structures of benzene before moving onto the main teaching activities.

## Main teaching ideas

### 1 Electrophilic substitution mechanism (60 minutes)

**Resources:** Phenol and Br<sub>2</sub>, if available, for demonstration. Alternatively, search the internet with the keywords 'phenol' and 'bromine reaction' and there are videos available. Coursebook sub-chapter 22.6 and the internet.

**Description and purpose:** A quick demonstration of the reaction between phenol and bromine to show electrophilic substitution on the benzene ring. The teacher can explain the balanced equation and ask students to explain why it is 'electrophilic' and why it is 'substitution' instead of 'addition'. Students draw the general mechanism for the reaction between benzene and an electrophile.

#### > Differentiation ideas:

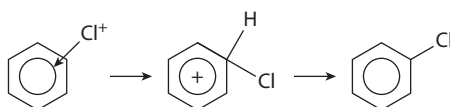
**Support:** Teacher-led discussion on why benzene attracts electrophiles and why it is more likely to undergo substitution reactions rather than addition. The teacher helps to draw the general mechanism for the substitution of benzene.

**Stretch and challenge:** Students can research the nitration of benzene mechanism using Coursebook sub-chapter 22.6. They then present information to the rest of the class, including information on how the electrophile is formed and how the sulfuric acid catalyst is regenerated. In addition, they can use the Royal Society of Chemistry's mechanism inspector to study other substitution reactions of benzene.

## Plenary ideas

### 1 Spot the mistake in the mechanism of benzene with Cl<sup>+</sup> electrophile (10 minutes)

**Resources:** A wrongly labelled mechanism, for example:



**Description and purpose:** Students need to spot the mistakes in the mechanism drawn and correct them. This activity assesses students' understanding of electrophilic substitution and if they can apply their knowledge in an unfamiliar situation.

## Assessment ideas

- Ask students to draw mechanisms for specific reactions (nucleophilic substitution, electrophilic addition, and electrophilic substitution) and peer assess their answers. Students can use two stars and a wish to comment on each other's work.
- Divide students into groups to produce a summary of the similarities and differences between S<sub>N</sub>1 and S<sub>N</sub>2 mechanisms. They need to give specific examples of nucleophilic substitution to illustrate the mechanisms.
- Test your understanding questions from the Coursebook.

## Homework ideas

- Write a glossary for the keywords from this chapter: nucleophile, electrophile, carbocation,  $S_N1$ ,  $S_N2$ , halogenoalkane, substitution, addition, Lewis acid, Lewis base, coordination bond, complex ion, oxidation state. An example should be given to show the level of detail required for the definitions.
- Exercises 22.1–22.6 from the Workbook.
- Exam-style questions from the Coursebook.
- Use the mechanism inspector to revise the mechanisms included in this chapter. The mechanism inspector can be found on the Royal Society of Chemistry website.
- Use traffic lights to self-assess the success criteria for the chapter.
- Create a flowchart of reaction pathways to assess the students' confidence with converting functional groups and their familiarity with the reagents and conditions required for each reaction.

## Links to digital resources

- Protocol for the [relative rates](#) of  $S_N2$  reactions
- Mechanism cards for  $S_N2$  reactions (search the Royal Society of Chemistry website with the keywords 'mechanism cards' and '[nucleophilic substitution](#)')
- Information on the choice between  $S_N1$  and  $S_N2$  mechanisms (search the internet for 'Chemguide' and '[nucleophilic substitution](#)')
- Mechanism inspector (search the Royal Society of Chemistry website with the keywords '[mechanism inspector](#)')

### CROSS-CURRICULAR LINKS

- TOK: How does scientific knowledge progress? Why are there different theoretical approaches to the same observation (for example, the explanation of substitution reactions using nucleophiles / electrophiles or Lewis bases / acids)?