21 Electron sharing reactions

Teaching plan

Sub-chapter	Approximate number of learning hours	Learning content	Resources
21.1 Radicals 21.2 The radical substitution mechanism	1–2	Define what radicals are. Identify radicals in a chemical reaction and know how to represent them. Explain how radicals can be produced by homolytic fission and represent the process with equations. Write equations for the propagation and termination steps for the free radical substitution mechanism of alkanes.	**Coursebook** Sections 21.1–21.2 **Workbook** Exercises 21.1–21.2 **Teacher's resource** PowerPoint 21, slides 2–6 Worksheet 21.1 End of Chapter 21 test Questions 1–8

BACKGROUND KNOWLEDGE

- Deduce Lewis formulas of molecules and ions (Chapter 7).
- Recall the structures, functional groups and naming of alkanes and halogenoalkanes (Chapter 11).
- Propose and evaluate reaction mechanisms (Chapter 17).

Syllabus overview

- In Chapter 17, collision theory and the idea that it is highly improbable for more than two particles to collide at any instant are introduced. Therefore, reactions mostly occur in a series of elementary steps through the formation of intermediates.
- In this chapter, the free radical substitution of alkanes is presented to show how each of its elementary steps happens. Curly arrows are used to illustrate the movements of electrons in bond breaking and bond formation. Students must try not to merely memorise the mechanism, but to understand the driving force for each step and why / how some bonds are broken more easily than others.
- The definitions of radicals and homolytic fission should be explained.

21.1 Radicals and 21.2 The radical substitution mechanism

LEARNING PLAN

Learning objectives	Success criteria
Understand what a radical is Understand the radical substitution reactions of alkanes with halogens	Students can identify radicals and explain how they are formed. Students can describe the steps in the radical substitution mechanism between alkanes and halogens.

Common misconceptions

Misconceptions	How to identify	How to overcome
Students confuse substitution reactions and addition reactions	Demonstrate experiments of hexane and hexene with bromine water. Ask students the difference between these two reactions and ask them to explain why the reaction of hexane with bromine water is slower and requires UV light / sunlight.	Write out the structures of hexane and hexene, showing the presence of double bonds in hexene molecules. Use molecular models or other modelling kits to show how bromine can be added onto an unsaturated compound rather than being substituted into a saturated compound.

Starter ideas

1 Dot-and-cross diagrams (10 minutes)

Resources: A periodic table, a mini-whiteboard, pens.

Description and purpose: Students draw dot-and-cross diagrams (use dots and crosses, rather than lines, to represent electrons) for the following species: Cl, Cl^-, Cl_2, CH_4, C_2H_6, NO, NO_2, N_2, CH_3Cl.

What to do next: Help students revise knowledge from Chapter 7. If they are confident with drawing out valence electron distributions, introduce the concept of a free radical and ask students to identify the radicals from the above list.

Main teaching ideas

1 Free radical substitution mechanisms (60 minutes)

Resources: Hexane, bromine water, boiling tubes, Coursebook sub-chapter 21.2, and molecular models.

Description and purpose: The teacher demonstrates the free radical substitution of hexane with a halogen. Mix hexane and bromine water in a boiling tube and decolourisation only occurs in the presence of UV light. Students use Coursebook sub-chapter 21.2 or the internet to research the three-step mechanism of this reaction, summarising information before presenting to the rest of the class. The explanation should include 1) the definitions of radicals; 2) how they are formed through homolytic fission; 3) how to represent homolytic fission using single-barbed arrows and 4) the equations for initiation, propagation and termination steps.

› **Language focus:** Students can explain the mechanism and definitions correctly and precisely, with the use of relevant equations and symbols.

› **Differentiation ideas:**

Support: Students are grouped by ability, so the teacher can provide support accordingly. For example, show the overall equation of the reaction, build molecular models to illustrate where substitution occurs, and explain how the electrons move during bond breaking and bond formation using animation. An example of the animation can be found on the Khan Academy website (see the Link to digital resources section).

Stretch and challenge: When students are able to draw the mechanisms independently, they can work out and explain how many different mono-substituted products there are for hexane reacting with bromine. They can research further into the use of antioxidants to reduce the number of free radicals.

Plenary ideas

1 Fill in the gaps in the following mechanisms (10 minutes)

Resources: A mechanism for the reaction between ethane and bromine, with some species missing. For example:

1 _____ Br—Br → 2Br• (add curly arrows in this step)

2 Propagation Br• + C_2H_6 → _____ + _____

3 _____ + Br_2 → _____+ Br•

4 _____ 2Br• → Br_2

5 _____ + Br• → _____

6 _____ + _____ → C_4H_{10}

Description and purpose: Students need to apply their knowledge of free radical substitution and work out the missing formulas / single-barbed arrows. Students can explain the three-step mechanism in the mono-substitution of ethane with bromine to a peer.

2 A multiple choice question on the mono-substitution of alkanes (10 minutes)

Resources: How many mono-substituted products are there for the reaction between 2-methylbutane and chlorine in the presence of UV light?

A 2 **B** 3 **C** 4 **D** 5

Description and purpose: Students need to draw out the correct structure of the alkane and consider the symmetry in the molecule. The correct answer is C.

Assessment ideas

- Give students a list of different species to identify radicals.
- Correct mistakes in a free radical substitution mechanism.
- Test your understanding questions from the Coursebook.

Homework ideas

- Exercises 21.1 and 21.2 from the Workbook.
- Exam-style questions from the Coursework.
- Extra practice questions on free radical substitution; search the internet for the keywords *Chemguide* and *free radical substitution*.
- Make flashcards for remembering the definitions of free radical and homolytic fission.

Links to digital resources

- Animation of the free radical substitution mechanism
- For extra practice questions search the internet with the keywords 'Chemguide' and 'free radical substitution questions'

CROSS-CURRICULAR LINK

- TOK: What is the impact of scientific discoveries on our environment?