21.1 Electron sharing: radicals

Name: _____ Class: _____ Date: _____ **Total: 20 marks**

KEY WORDS radical • homolytic fission • initiation • propagation • termination • substitution

Objective

Build the skills to answer exam questions on **electron sharing reactions** : radicals, homolytic fission and the substitution of alkanes.

You must be able to:

- define a radical and describe homolytic fission
- write the initiation, propagation and termination steps for the reaction of an alkane with a halogen
- explain the conditions needed and why a mixture of products forms

1 Key knowledge and worked examples

Radicals

A **radical** is a species with an **unpaired electron**, shown by a dot: $Cl^{\bullet}$, $CH_3^{\bullet}$. Radicals are very reactive.

Homolytic fission: a covalent bond breaks and **each atom takes one electron**: Cl–Cl → $2Cl^{\bullet}$. It needs **UV light** (or high temperature).

Alkane + halogen (UV light): radical substitution. $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$.

stage	what happens	example
initiation	radicals are made	$Cl_2 \rightarrow 2Cl^{\bullet}$
propagation	a radical reacts and makes a new radical	$Cl^{\bullet} + CH_4 \rightarrow CH_3^{\bullet} + HCl$; $CH_3^{\bullet} + Cl_2 \rightarrow CH_3Cl + Cl^{\bullet}$
termination	two radicals join, so radicals are removed	$Cl^{\bullet} + CH_3^{\bullet} \rightarrow CH_3Cl$

Propagation is a **chain reaction**: one $Cl^{\bullet}$ can cause thousands of reactions. Further substitution (CH_2Cl_2, $CHCl_3$, CCl_4) and termination (C_2H_6) give a **mixture of products**.

Worked example 1: a radical. $Br^{\bullet}$ has 7 outer electrons, one of them **unpaired**.

Worked example 2: propagation. $Br^{\bullet} + C_2H_6 \rightarrow \mathbf{C_2H_5^{\bullet}} + \mathbf{HBr}$.

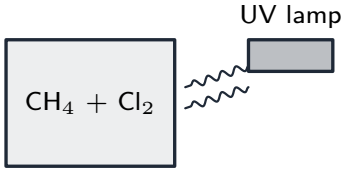
Answer shapes: put the dot on every radical; in propagation a radical appears on both sides.

2 Practice

2.1 Define a radical, and describe what happens to the bonding electrons in homolytic fission. [2]

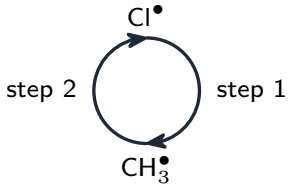


2.2 Write the equation for the initiation step when chlorine reacts with methane, and state the condition needed. Explain why this condition is needed. [3]



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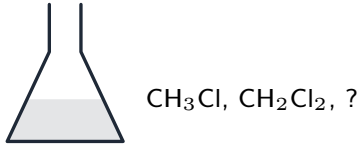
2.3 Write the two propagation steps that form chloromethane, and explain why this is called a chain reaction. [3]



2.4 Write two possible termination steps, and explain why termination stops the reaction. [3]



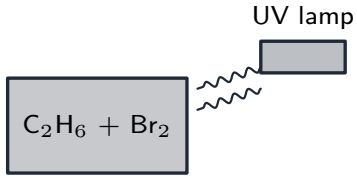
2.5 Explain why the reaction of methane with excess chlorine gives a mixture of products, and give one example of another product. [2]



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3 Exam-style questions

3.1 Ethane reacts with bromine in ultraviolet light.



(a) Write the overall equation for the formation of bromoethane. [1]

(b) Name the type of reaction. [1]

(c) Write the initiation step and the two propagation steps. [3]

(d) Explain why no reaction happens in the dark at room temperature. [1]

(e) A small amount of butane, C_4H_{10}, is also formed. Explain how. [1]

Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

a species with an unpaired electron; the bond breaks and each atom takes one of the two electrons

2.2

$Cl_2 \rightarrow 2Cl^{\bullet}$; UV light; it provides the energy to break the Cl–Cl bond

2.3

$Cl^{\bullet} + CH_4 \rightarrow CH_3^{\bullet} + HCl$; $CH_3^{\bullet} + Cl_2 \rightarrow CH_3Cl + Cl^{\bullet}$; the $Cl^{\bullet}$ used is made again, so the cycle repeats many times

2.4

any two: $Cl^{\bullet} + Cl^{\bullet} \rightarrow Cl_2$; $CH_3^{\bullet} + Cl^{\bullet} \rightarrow CH_3Cl$; $CH_3^{\bullet} + CH_3^{\bullet} \rightarrow C_2H_6$; two radicals are used up and no new radical forms

2.5

$Cl^{\bullet}$ can also remove H from chloromethane, so further substitution happens; e.g. CH_2Cl_2 / $CHCl_3$ / CCl_4

3.1

(a) $C_2H_6 + Br_2 \rightarrow C_2H_5Br + HBr$

(b) (radical) substitution

(c) $Br_2 \rightarrow 2Br^{\bullet}$; $Br^{\bullet} + C_2H_6 \rightarrow C_2H_5^{\bullet} + HBr$; $C_2H_5^{\bullet} + Br_2 \rightarrow C_2H_5Br + Br^{\bullet}$

(d) UV light is needed to break the Br–Br bond and make radicals

(e) termination: two ethyl radicals join, $C_2H_5^{\bullet} + C_2H_5^{\bullet} \rightarrow C_4H_{10}$

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