21.1 Electron-pair sharing: nucleophiles and electrophiles

Name: _____ Class: _____ Date: _____ **Total: 24 marks**

KEY WORDS nucleophile • electrophile • heterolytic fission • nucleophilic substitution • electrophilic addition • carbocation

Objective

Build the skills to answer exam questions on **electron-pair sharing reactions** : nucleophiles, electrophiles, substitution of halogenoalkanes and addition to alkenes.

You must be able to:

- define nucleophile and electrophile and identify them in reactions
- describe heterolytic fission
- write equations for nucleophilic substitution of halogenoalkanes and electrophilic addition to alkenes

1 Key knowledge and worked examples

Nucleophiles and electrophiles

Heterolytic fission: a bond breaks and **one atom takes both electrons**, making ions: H–Br → H^+ + Br^-.

	nucleophile	**electrophile**
definition	electron-pair **donor**	electron-pair **acceptor**
attracted to	$\delta+$ atoms / positive centres	electron-rich regions (C=C)
examples	OH^-, H_2O, NH_3, CN^-	H^+, NO_2^+, Br_2 (polarized)

Nucleophilic substitution: in a halogenoalkane the C–X carbon is $\delta+$. CH_3CH_2Br + OH^- → CH_3CH_2OH + Br^- (warm, aqueous NaOH).

Electrophilic addition: alkenes have an electron-rich C=C. C_2H_4 + Br_2 → CH_2BrCH_2Br. **Test:** bromine water turns from orange to colourless.

Worked example 1: identify. In NH_3 + CH_3Cl, NH_3 uses its lone pair: it is the **nucleophile**.

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Worked example 2: product. Propene + Br_2 → **1,2-dibromopropane**, $CH_3CHBrCH_2Br$.

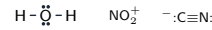
Answer shapes: "donates an electron pair to the $\delta+$ carbon"; name products with numbers.

2 Practice

2.1 Define the terms nucleophile and electrophile. [2]



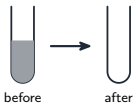
2.2 Classify each species as a nucleophile or an electrophile: H_2O, NO_2^+, CN^-. [3]



2.3 Bromoethane is warmed with aqueous sodium hydroxide. Write the equation, name the organic product and name the type of reaction. [3]



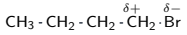
2.4 Bromine water is shaken with ethene. State what you see, write the equation, and name the type of reaction. [3]



3 Exam-style questions

3.1 1-bromobutane and 1-chlorobutane both react with aqueous hydroxide ions.

(a) Explain why the carbon bonded to the halogen is attacked by nucleophiles. [2]



(b) Predict which compound reacts faster, and explain. [2]

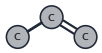
(c) Name the organic product formed from 1-bromobutane. [1]

(d) Name the type of fission in which the C–Br bond breaks. [1]

3.2 Propene, $CH_3CH{=}CH_2$, is an alkene.

(a) Describe a test for an alkene and its result. [1]

(b) Write the equation for propene reacting with bromine, and name the product. [2]



(c) Propene reacts with steam to form an alcohol. State one catalyst for this reaction, and name a possible product. [2]

(d) Bromine molecules are non-polar. Explain why bromine still acts as an electrophile. [2]

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Solutions

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

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

2.1

nucleophile: an electron-pair donor; electrophile: an electron-pair acceptor

2.2

H_2O nucleophile; NO_2^+ electrophile; CN^- nucleophile

2.3

$CH_3CH_2Br + OH^- \rightarrow CH_3CH_2OH + Br^-$; ethanol; nucleophilic substitution

2.4

orange to colourless; $C_2H_4 + Br_2 \rightarrow CH_2BrCH_2Br$; electrophilic addition

3.1

(a) the halogen is more electronegative, so the carbon is $\delta+$; it attracts the lone pair of the nucleophile

(b) 1-bromobutane; the C–Br bond is weaker than the C–Cl bond, so it breaks more easily

(c) butan-1-ol

(d) heterolytic

3.2

(a) shake with bromine water: orange to colourless

(b) $CH_3CH{=}CH_2 + Br_2 \rightarrow CH_3CHBrCH_2Br$; 1,2-dibromopropane

(c) phosphoric acid / sulfuric acid; propan-2-ol / propan-1-ol

(d) the electron-rich C=C repels the electrons in Br_2, so the molecule becomes polarized; the $\delta+$ bromine atom accepts an electron pair from the C=C

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