# 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**, $CH_3CHBrCH_2Br$.

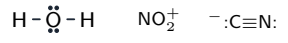
**Answer shapes:** "donates an electron pair to the $\delta+$ carbon"; name products with numbers.

## 2 Practice

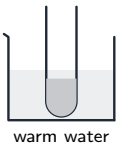
**2.1** Define the terms nucleophile and electrophile. [2]



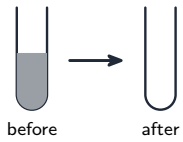

**2.2** Classify each species as a nucleophile or an electrophile: $H_2O$, $NO_2^+$, $CN^-$. [3]




**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]



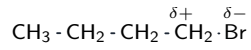



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## 3 Exam-style questions

**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]

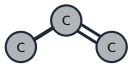
(c) Name the organic product formed from 1-bromobutane. [1]

(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