Reactivity 3.4 · Electron-pair sharing reactions · supported focus

International Baccalaureate · IB Diploma · Chemistry · HL

Scope and prerequisites

Supported HL/SL core focus. First assessment 2025; current brief acquired; full Chemistry guide not acquired. Remaining guide, assessment and practical requirements retain their recorded holds.

Prerequisites: covalent bonding and polarity from Structure 2.2, alkenes and halogenoalkanes from Structure 3.2, and radical (electron-sharing) mechanisms from Reactivity 3.3. Each lesson develops its own method before independent transfer.

These are original or explicitly fictional teaching examples, not actual measurements or completed assessed learner investigations.

Electron-pair sharing reactions

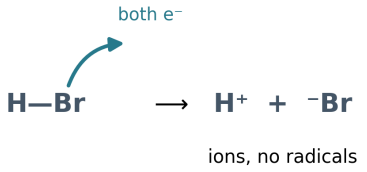
■ What would explain this observation?

- Bromoethane shaken with warm sodium hydroxide solution turns into ethanol, while the same alkane skeleton with no C–Br bond ignores the hydroxide completely. What does the C–Br bond make possible?
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

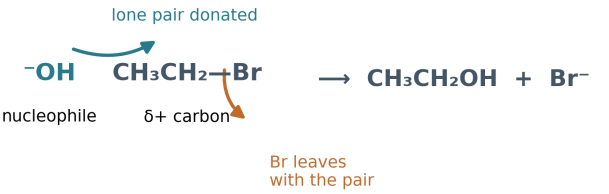
- A covalent bond can also break by **heterolytic fission**: BOTH electrons of the shared pair move to one atom, forming ions. A double-barbed curly arrow shows an electron PAIR moving.
- A **nucleophile** is an electron-pair donor (OH^-, CN^-, NH_3) that attacks a $\delta+$ carbon. An **electrophile** is an electron-pair acceptor (Br_2, H^+) that accepts a pair from an electron-rich region such as a C=C double bond. In the substitution of bromoethane, OH^- donates its pair to the $\delta+$ carbon while Br^- leaves with the bonding pair: $CH_3CH_2Br + OH^- \rightarrow CH_3CH_2OH + Br^-$.
- heterolytic fission: Bond breaking where one atom takes both shared electrons; nucleophile: An electron-pair donor attracted to a positive or $\delta+$ centre; electrophile: An electron-pair acceptor attracted to an electron-rich region.

Heterolytic fission: the PAIR moves to one atom



Double-barbed arrows move an electron PAIR

Nucleophilic substitution: OH^- attacks bromoethane



Nucleophile = electron-pair donor; electrophile = electron-pair acceptor

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Choose evidence that can test it

- The reaction rate depends on the concentrations of BOTH bromoethane and hydroxide, supporting a mechanism in which both meet in the key step. Bromide ions appear in solution as the alcohol forms, matching the leaving-group prediction.
- Bromine water loses its orange colour with an alkene but not with the corresponding alkane – evidence that the electron-rich C=C is what attracts the electrophile.

Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: $Mr(CH_3CH_2OH) = 46$; $Mr(CH_3CH_2Br) = 109$; $Mr(OH^-) = 17$. Atom economy measures how much reactant mass ends in the desired product: atom economy = Mr(desired product) / ΣMr(all reactants) × 100%. Substitution: 46/(109 + 17) × 100% = 46/126 × 100% = 36.5%. Substitution reactions have low atom economy because the leaving group carries mass away.

Example:

Chloroethane has Mr = 64.5. Find the atom economy of $CH_3CH_2Cl + OH^- \rightarrow CH_3CH_2OH + Cl^-$ using the same sequence: known quantities → model → relation → substitution → unit and interpretation. (Answer: 46/(64.5 + 17) × 100% = 46/81.5 × 100% = 56.4% – a lighter leaving group raises the atom economy, though it is still far below an addition reaction's 100%.)

Check the conclusion and its limits

- The arrow-pushing model shows electron flow in the key step; real rates also depend on the solvent and temperature, which this scheme does not capture. Atom economy compares routes on paper; a full process evaluation needs yield, energy and safety data too.

- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A nucleophile is a negative ion, so any negative ion is a nucleophile and any positive species is an electrophile. This claim is false: the definition is about electron-PAIR donation – neutral NH_3 is a nucleophile because it carries a lone pair, and Br^- is a leaving group, not an attacking nucleophile, in this substitution.

Key:

Electron-pair sharing reactions: heterolytic fission moves both shared electrons to one atom; double-barbed arrows track electron pairs. Nucleophiles donate pairs to $\delta+$ centres and electrophiles accept pairs from electron-rich regions; substitution and addition mechanisms follow from that flow.