

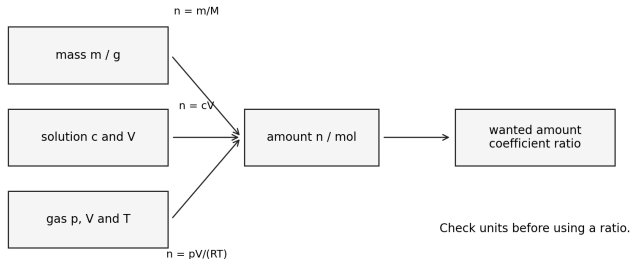
Unit 1: Structure, bonding and organic introduction

Pearson YCH11 · acquired specification Topics 1–5 · authentic bank holds remain explicit

Two languages of chemistry

- 1** Use particle models to explain properties, then balanced equations to calculate amounts.
- 2** Prerequisites: algebra, powers of ten and conservation of atoms and charge.

Choose a route to amount



Convert known quantities to moles before applying a coefficient ratio.

Known mass to predicted gas volume

- 1 **1** $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$; acid in excess.
- 2 **2** $n(\text{Mg}) = m/M = 0.480 \text{ g} / (24.0 \text{ g mol}^{-1}) = 0.0200 \text{ mol}$.
- 3 **3** 1:1 ratio gives $n(\text{H}_2) = 0.0200 \text{ mol}$.
- 4 **4** $V = nV_m = 0.0200 \text{ mol} \times 24 \text{ dm}^3 \text{ mol}^{-1} = 0.48 \text{ dm}^3$.

Particle counting: your turn

Your turn

How many atoms are in 0.100 mol of CH_4 molecules? Use $L = 6.02 \times 10^{23} \text{ mol}^{-1}$.

- A. 6.02×10^{22}
- B. 3.01×10^{23}
- C. 2.41×10^{23}
- D. 0.500

One molecule contains five atoms

- 1 Each CH_4 molecule has one C and four H atoms.
- 2 $N_{\text{atoms}} = 5nL = 5 \times 0.100 \text{ mol} \times 6.02 \times 10^{23} \text{ mol}^{-1} = 3.01 \times 10^{23}$.
- 3 Option B; option A counts molecules and C counts only hydrogen atoms.

Formulae are checked by mass conservation

- 1** Divide each element mass by its atomic molar mass; form the simplest whole-number ratio.
- 2** Multiply every empirical subscript by measured molecular mass / empirical mass.
- 3** Balanced equations conserve atoms and charge; coefficients change, substance formulae do not.

Yield and atom economy ask different questions

- 1** Percentage yield = actual product mass / theoretical product mass $\times$ 100%.
- 2** Atom economy = balanced desired-product mass / all balanced product masses $\times$ 100%.
- 3** Include coefficients. A high atom economy does not remove practical losses.

Experiments can bias a correct equation

- 1 Known limiting amount $\rightarrow$ collect gas $\rightarrow$ record volume, temperature and pressure.
- 2 A leak lowers collected volume, so inferred molar gas volume is too small.
- 3 For a formula by oxidation, heat to constant mass and avoid losing solid.

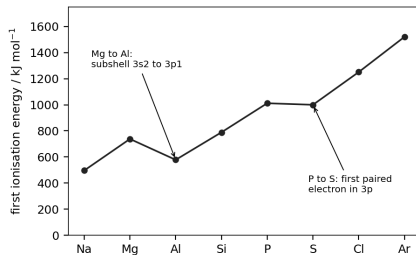
Read mass-to-charge before mass

- 1** Mass spectrometry forms positive gas ions, accelerates and separates them by m/z , then detects abundance.
- 2** A doubly charged mass-40 ion gives $m/z = 20$. Lower m/z bends more in magnetic separation.
- 3** For chlorine isotope proportions 3:1, Cl_2 peaks 70:72:74 have heights 9:6:1.

Orbitals are not planetary tracks

- 1** An s orbital is spherical; a p orbital has two lobes. Each orbital holds at most two opposite-spin electrons.
- 2** s, p and d subshells contain 1, 3 and 5 orbitals: capacities 2, 6 and 10.
- 3** Fill equal-energy orbitals singly first. Cr is $[\text{Ar}]3\text{d}^54\text{s}^1$; Cu is $[\text{Ar}]3\text{d}^{10}4\text{s}^1$.
Remove 4s first for their ions.

Explain the ionisation-energy dips



Period 3 generally rises as nuclear charge increases with similar inner shielding.

What does a jump establish?

Your turn

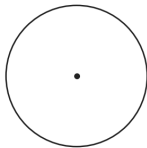
Three successive ionisation energies are close; the fourth is much larger. What follows from the jump alone?

- A. Three outer electrons; period still unknown
- B. Period 3; group still unknown
- C. Four outer electrons
- D. The atom has four occupied shells

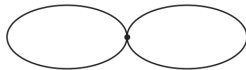
Separate inference from recognition

- 1** Option A: three outer electrons were removed before an inner-shell electron.
- 2** This supports main Group 3/13. The limited list does not count all occupied shells.
- 3** Recognising familiar numerical values is additional evidence, not the jump itself.

Orbitals hold electrons in pairs



s orbital: spherical



one p orbital: two lobes

P: $[\text{Ne}]3s^23p^3$



3s

three 3p orbitals

S adds $\downarrow$ to one 3p box.

Each orbital holds at most two electrons with opposite spins. Fill the three equal-energy p orbitals singly before pairing.

Your turn: configurations determine the block

- 1 Classify K, Sc, As and He into s, p or d blocks.
- 2 Use $4s^1$, $3d^14s^2$, $4p^3$ and $1s^2$. Explain the helium exception.

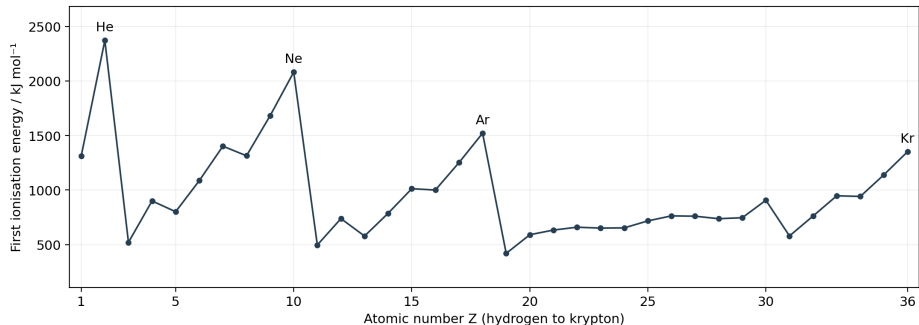
Helium is s-block with noble-gas behaviour

- 1 K: s; Sc: d; As: p.
- 2 He: $1s^2$ is s-block, although it occupies the noble-gas column.

Your turn: graph every atom through krypton

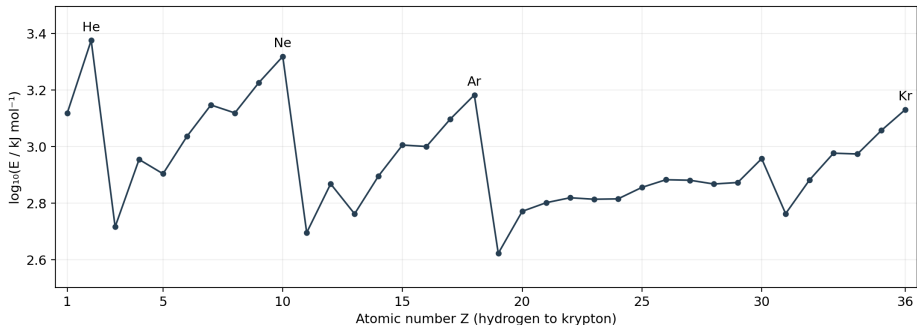
- 1 Use all 36 supplied first-ionisation values on sheet 1.2.2.
- 2 Draw linear and $\log_{10}$ plots. Label noble-gas peaks and shell-start decreases.

The first 36 energies on a linear axis



New-shell decreases follow He, Ne and Ar; internal dips also occur.

A logarithmic axis compares ratios



The order is unchanged; equal vertical distances represent equal ratios.

Your turn: explain Period-2 melting

- 1 Classify Li/Be, B/C, N₂/O₂/F₂ and Ne by solid structure.
- 2 Explain carbon versus nitrogen without using ionisation energy as the melting process.

Melting changes the structure of the solid

- 1 Li/Be metallic; B/C giant covalent.
- 2 N₂/O₂/F₂ molecular; Ne monatomic.
- 3 Carbon requires overcoming strong network bonds; nitrogen retains N≡N.

Explain a bulk property with mobile particles

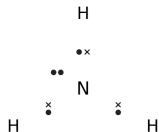
- 1** Ionic lattice: strong net attraction; fixed ions cannot carry current in the solid.
- 2** Molten/dissolved ions can move. Metals conduct through delocalised electrons.
- 3** Small molecular substances usually boil by overcoming intermolecular attractions.

Count pairs before naming shape

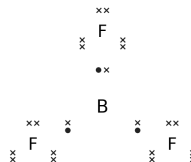
- 1 **1** NH_4^+ and CH_4 : four bonding regions, tetrahedral, 109.5° .
- 2 **2** NH_3 : three bonds and one lone pair, pyramidal, about 107° . H_2O : two bonds and two lone pairs, bent, about 104.5° .
- 3 **3** Lone pairs repel more strongly; the angle reduction is not a fixed amount per pair.

Dots and crosses are an electron account

Dots: central atom Crosses: outer atoms
Flat electron diagrams do not show the 3D shape.



NH_3 : 3 bond pairs + 1 lone pair



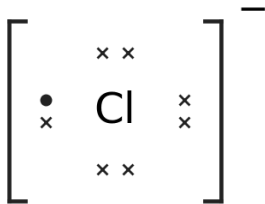
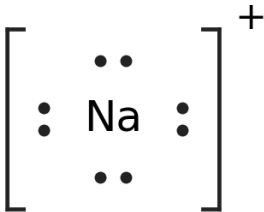
BF_3 : 3 bond pairs; B has 6 outer electrons

Shared pairs identify covalent bonds. Lone pairs must also be shown.

Polarity is a vector question

- 1 Electronegativity differences create bond dipoles.
- 2 CO_2 has polar bonds whose dipoles cancel; water is bent and its dipoles do not cancel.
- 3 A small highly charged cation polarises an anion; larger anions distort more easily.

Draw ions with brackets and charges



NaCl: bracketed ions; only each ion's outer shell shown.

Each ion has a full outer shell. The gained chloride electron comes from sodium.

Include every oxygen lone pair

CO₂: dots from C; crosses from O



Two shared pairs per C–O bond; two lone pairs per O.

Each C–O double bond has two shared pairs; each oxygen has two lone pairs.

A triple bond uses six shared electrons

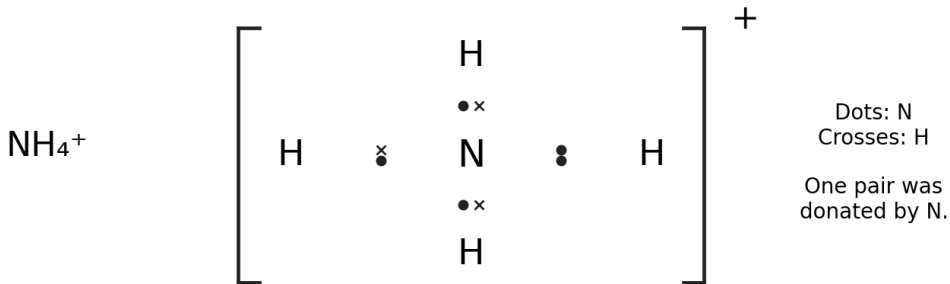
N₂: dots from left N; crosses from right N



Three shared pairs and one lone pair per atom: ten outer electrons.

N₂ has ten outer electrons: three shared pairs and one lone pair per nitrogen atom.

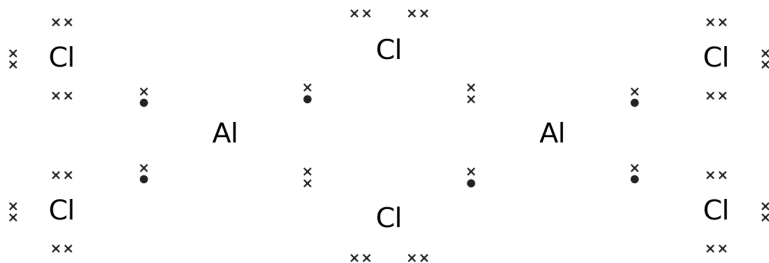
Track the nitrogen donor pair



NH_4^+ has eight outer electrons. One original shared pair comes entirely from nitrogen.

Count every bridging chlorine electron

Al_2Cl_6 : dots from Al; crosses from Cl



Each bridging Cl donates a pair to the other Al. All 48 outer electrons are shown.

Each bridging chlorine supplies a pair to the other aluminium; Al_2Cl_6 has 48 outer electrons.

Read and name a carbon skeleton

- 1 Every skeletal end/corner is C; add implied H to give carbon four bonds.
- 2 Acyclic alkanes: C_nH_{2n+2} . Single-ring cycloalkanes: C_nH_{2n} . Both are saturated.
- 3 Structural isomers share a molecular formula but differ in atom connectivity.

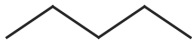
Follow a radical chain

- 1** Initiation: $Cl_2 \rightarrow 2Cl\cdot$ in UV light; homolytic cleavage gives one electron to each fragment.
- 2** Propagation: $Cl\cdot + CH_4 \rightarrow HCl + CH_3\cdot$; $CH_3\cdot + Cl_2 \rightarrow CH_3Cl + Cl\cdot$.
- 3** Termination: $2CH_3\cdot \rightarrow C_2H_6$. Further substitution gives mixtures.

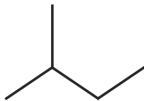
Compare fuels using their whole pathway

- 1** Cracking makes smaller hydrocarbons including alkenes; balance atoms in proposed products.
- 2** CO reduces oxygen transport; nitrogen/sulfur oxides can contribute to acid pollution.
- 3** Bioethanol growth can absorb CO_2 , but processing and transport still emit. Hydrogen production also matters.

Generate chains without duplicate numbering



pentane



2-methylbutane



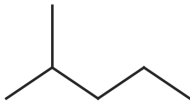
2,2-dimethylpropane

Pentane has three constitutional isomers: start with the longest chain, then branch.

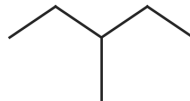
Hexane: three longest-chain choices



hexane



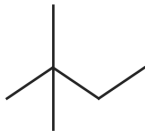
2-methylpentane



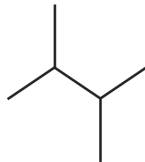
3-methylpentane

Hexane, 2-methylpentane and 3-methylpentane are distinct connectivities.

Hexane: finish with four-carbon parents



2,2-dimethylbutane



2,3-dimethylbutane

2,2-dimethylbutane and 2,3-dimethylbutane complete the five hexane structures.

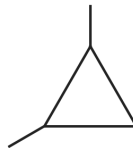
A ring can exchange carbons with side chains



cyclopentane



ethylcyclopropane



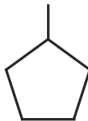
1,2-dimethylcyclopropane

Keep total carbon count and one saturated ring fixed while changing ring size and substituents.

Six carbons: start with large rings



cyclohexane



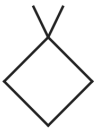
methylcyclopentane



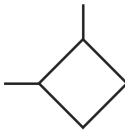
ethylcyclobutane

Begin with a six-carbon ring, then a five-carbon ring plus one carbon, then a four-carbon ring plus two.

Six carbons: distribute two methyl groups



1,1-dimethylcyclobutane



1,2-dimethylcyclobutane



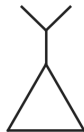
1,3-dimethylcyclobutane

On a four-carbon ring, the two extra carbons can occupy positions 1,1 or 1,2 or 1,3.

Six carbons: branch outside a three-carbon ring



propylcyclopropane



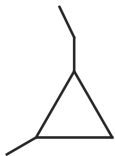
propan-2-ylcyclopropane



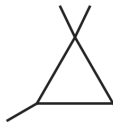
1-ethyl-1-methylcyclopropane

A three-carbon ring can carry propyl, propan-2-yl, or ethyl and methyl on one ring carbon.

Six carbons: distribute the remaining substituents



1-ethyl-2-methylcyclopropane



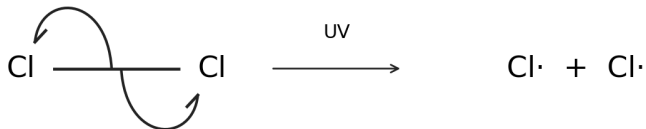
1,1,2-trimethylcyclopropane



1,2,3-trimethylcyclopropane

Finish with ethyl/methyl on different carbons and the two distinct trimethyl connectivities.

A half-arrow moves one electron

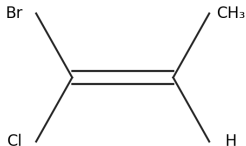


Homolysis: one electron from the bond goes to each chlorine atom.
Each curly half-arrow tracks one electron.

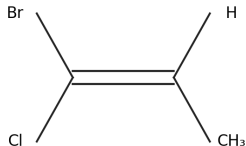
UV initiation splits the Cl–Cl bond homolytically: one electron goes to each atom.

Bond rotation and E/Z priorities

Assign priority separately on each double-bond carbon.



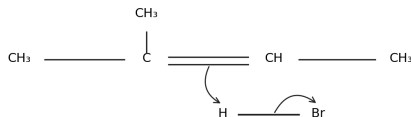
A: Z (Br and CH₃ together)



B: E (Br and CH₃ apart)

C=C has one sigma and one pi bond. Rotation would destroy pi overlap.

HBr addition follows the electron pair



H bonds to the CH carbon; C2 becomes a tertiary carbocation.



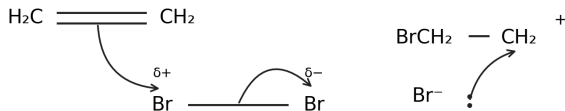
A bromide lone pair supplies the new bond to C⁺.
Product: CH₃-C(Br)(CH₃)-CH₂-CH₃ (2-bromo-2-methylbutane)

A curly arrow begins at the pi bond and ends at H; another sends the H-Br bonding pair to Br.

Choose reagents and conditions

- 1** H_2/Ni adds hydrogen; steam/acid catalyst adds water; Br_2 adds bromine across $\text{C}=\text{C}$.
- 2** Cold dilute acidified manganate(VII) gives a diol. Bromine decolourisation supports unsaturation, not a unique identity.
- 3** Addition polymerisation opens $\text{C}=\text{C}$, retains side groups and loses no small molecule.

Bromine addition moves electron pairs

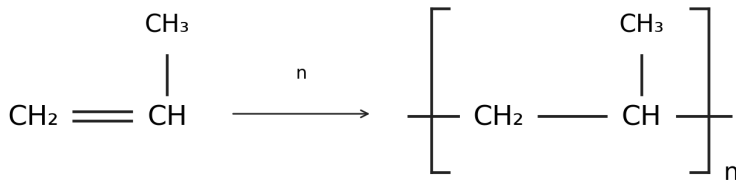


Product: $\text{BrCH}_2\text{-CH}_2\text{Br}$

Simple electrophilic-addition model: π pair $\rightarrow \text{Br}\delta^+$; Br-Br pair $\rightarrow \text{Br}\delta^-$.
A bromide lone pair supplies the second C-Br bond.

The π pair attacks $\text{Br}\delta^+$; the Br-Br pair moves to $\text{Br}\delta^-$. Bromide then supplies a pair to the positive carbon.

Keep the pendant group on its carbon

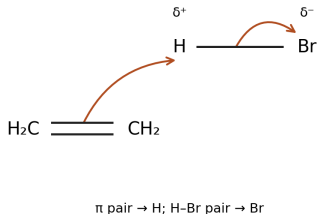


Propene → poly(propene); continuation bonds cross the brackets.
Side groups stay attached; no small molecule is eliminated.

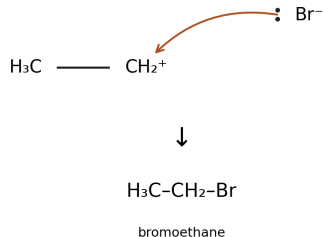
Open C=C into the polymer backbone, keep the methyl side group, and extend bonds through the brackets.

Ethene and HBr: follow both electron pairs

1 Form the ethyl carbocation



2 Bromide donates its lone pair



Equivalent ethene carbons give the same ethyl carbocation and bromoethane.

Final transfer: a biased measurement

Your turn

A 0.480 g sample produces 0.240 dm³ of gas in a 1:1 reaction. Use $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$. A leak makes gas volume too low. What happens to inferred sample molar mass?

- A. It is too high
- B. It is too low
- C. It stays correct
- D. It becomes negative

Check yourself

- 1** $n = V/V_m = 0.240 \text{ dm}^3 / (24.0 \text{ dm}^3 \text{ mol}^{-1}) = 0.0100 \text{ mol}.$
- 2** $M = m/n = 0.480 \text{ g} / (0.0100 \text{ mol}) = 48.0 \text{ g mol}^{-1}.$
- 3** Option A: a leak underestimates n ; dividing fixed mass by too small n overestimates M .