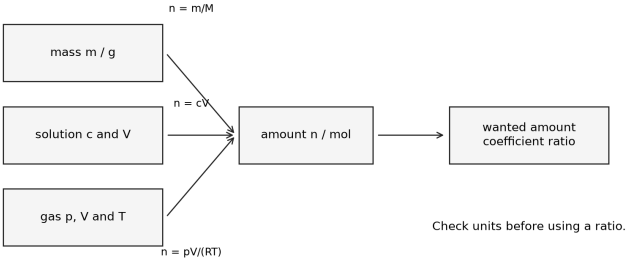
Unit 1: Structure, bonding and organic introduction

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

Two languages of chemistry

1. **1** Use particle models to explain properties, then balanced equations to calculate amounts.
2. **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** $\mathrm{Mg} + 2\mathrm{HCl} \rightarrow \mathrm{MgCl_2} + \mathrm{H_2}$; acid in excess.
2. **2** $n(\mathrm{Mg}) = m/M = 0.480\,g/(24.0\,g\,mol^{-1}) = 0.0200\,mol$.
3. **3** 1:1 ratio gives $n(\mathrm{H_2}) = 0.0200\,mol$.
4. **4** $V = nV_m = 0.0200\,mol \times 24\,dm^3\,mol^{-1} = 0.48\,dm^3$.

Particle counting: your turn

Your turn

How many atoms are in 0.100 mol of CH_4 molecules? Use $L = 6.02 \times 10^{23}$ 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. **1** Each CH_4 **molecule** has one C and four H atoms.
2. **2** $N_{atoms} = 5nL = 5 \times 0.100\,mol \times 6.02 \times 10^{23}\,mol^{-1} = 3.01 \times 10^{23}$.
3. **3** Option B; option A counts molecules and C counts only hydrogen atoms.

Formulae are checked by mass conservation

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

Yield and atom economy ask different questions

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

Experiments can bias a correct equation

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

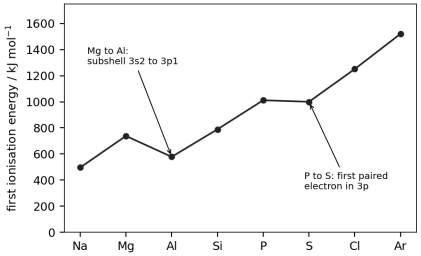
Read mass-to-charge before mass

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

Orbitals are not planetary tracks

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

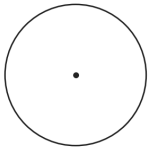
C. Four outer electrons

D. The atom has four occupied shells

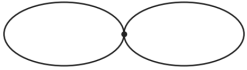
Separate inference from recognition

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

Orbitals hold electrons in pairs

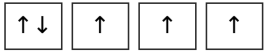


s orbital: spherical



one p orbital: two lobes

P: [Ne]$3s^2 3p^3$



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

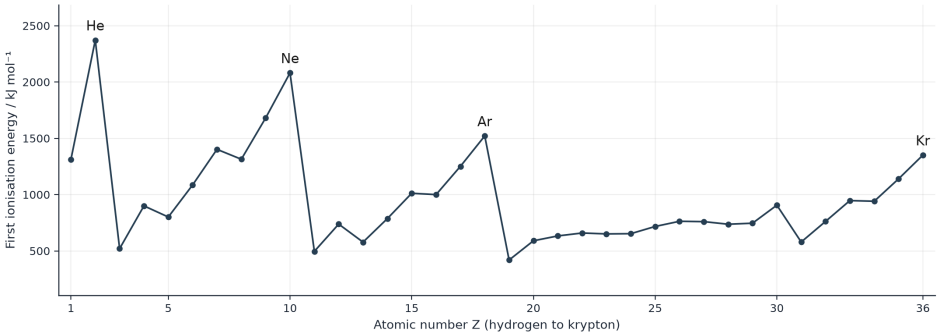
Helium is s-block with noble-gas behaviour

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

Your turn: graph every atom through krypton

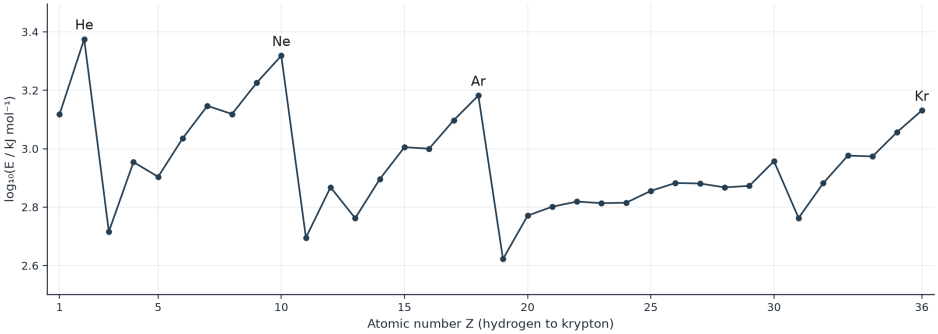
1. **1** Use all 36 supplied first-ionisation values on sheet 1.2.2.
2. **2** Draw linear and $\log_{10}$ plots. Label noble-gas peaks and shell-start decreases.

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. **1** Classify Li/Be, B/C, $N_2/O_2/F_2$ and Ne by solid structure.
2. **2** Explain carbon versus nitrogen without using **ionisation energy** as the melting process.

Melting changes the structure of the solid

1. **1** Li/Be metallic; B/C giant covalent.
2. **2** $N_2/O_2/F_2$ molecular; Ne monatomic.
3. **3** Carbon requires overcoming strong network bonds; nitrogen retains N≡N.

Explain a bulk property with mobile particles

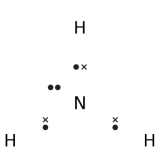
1. **1** Ionic lattice: strong net attraction; fixed ions cannot carry current in the solid.
2. **2** Molten/dissolved ions can move. Metals conduct through delocalised electrons.
3. **3** Small molecular substances usually boil by overcoming intermolecular attractions.

Count pairs before naming shape

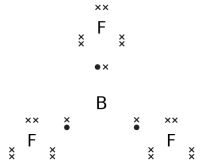
1. **1** NH_4^+ and CH_4: four bonding regions, tetrahedral, 109.5°.
2. **2** NH_3: three bonds and one lone pair, pyramidal, about 107°. H_2O: two bonds and two lone pairs, bent, about 104.5°.
3. **3** Lone pairs repel more strongly; the angle reduction is not a fixed amount per pair.

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. **1 Electronegativity** differences create bond dipoles.
2. **2** CO_2 has polar bonds whose dipoles cancel; water is bent and its dipoles do not cancel.
3. **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

CO_2: 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

N_2: dots from left N; crosses from right N

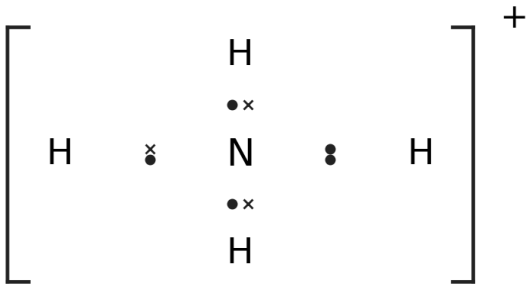


Three shared pairs and one lone pair per atom: ten outer electrons.

> N_2 has ten outer electrons: three shared pairs and one lone pair per nitrogen atom.

Track the nitrogen donor pair

NH_4^+



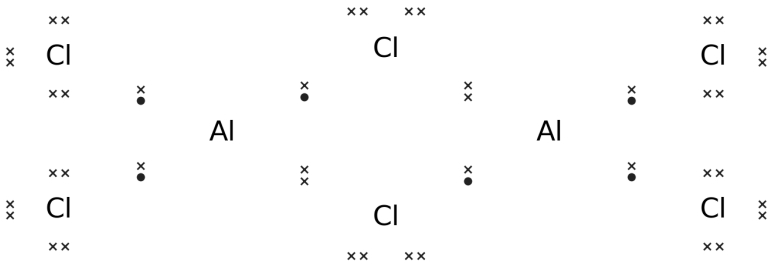
Dots: N
Crosses: H

One pair was donated by N.

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

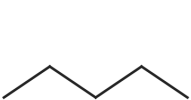
Follow a radical chain

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

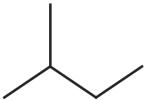
Compare fuels using their whole pathway

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

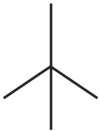
Generate chains without duplicate numbering



pentane



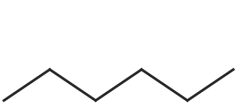
2-methylbutane



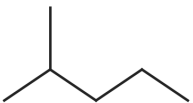
2,2-dimethylpropane

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

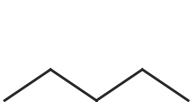
Hexane: three longest-chain choices



hexane



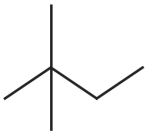
2-methylpentane



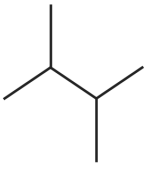
3-methylpentane

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

Hexane: finish with four-carbon parents



2,2-dimethylbutane



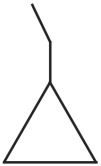
2,3-dimethylbutane

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

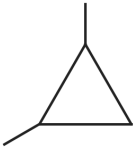
A ring can exchange carbons with side chains



cyclopentane



ethylcyclopropane



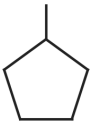
1,2-dimethylcyclopropane

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

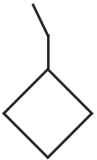
Six carbons: start with large rings



cyclohexane



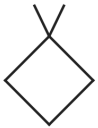
methylcyclopentane



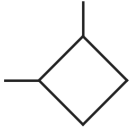
ethylcyclobutane

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

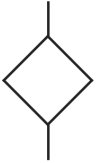
Six carbons: distribute two methyl groups



1,1-dimethylcyclobutane



1,2-dimethylcyclobutane



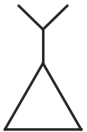
1,3-dimethylcyclobutane

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



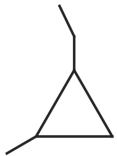
propan-2-ylcyclopropane



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



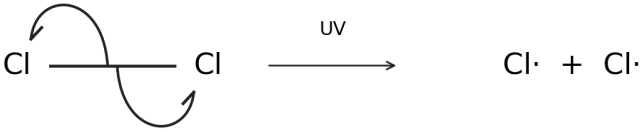
1,1,2-trimethylcyclopropane



1,2,3-trimethylcyclopropane

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

A half-arrow moves one electron

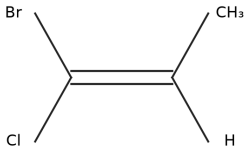


Homolysis: one electron from the bond goes to each chlorine atom.
Each curly half-arrow tracks one electron.

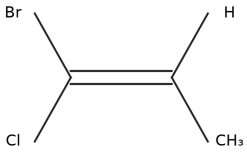
> UV initiation splits the Cl–Cl bond homolytically: one electron goes to each atom.

Bond rotation and E/Z priorities

Assign priority separately on each double-bond carbon.



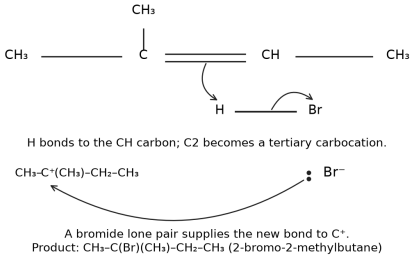
A: Z (Br and CH_3 together)



B: E (Br and CH_3 apart)

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

HBr addition follows the electron pair

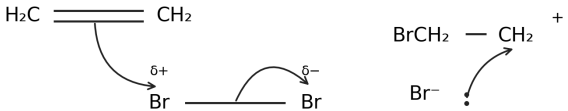


A curly arrow begins at the **pi bond** and ends at H; another sends the H–Br bonding pair to Br.

Choose reagents and conditions

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

Bromine addition moves electron pairs

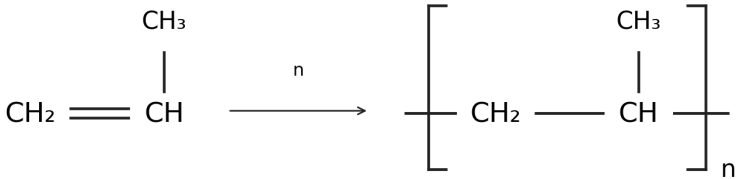


Product: $BrCH_2–CH_2Br$

Simple electrophilic-addition model: π pair → Brδ⁺; Br–Br pair → Brδ⁻.
A bromide lone pair supplies the second C–Br bond.

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

Keep the pendant group on its carbon

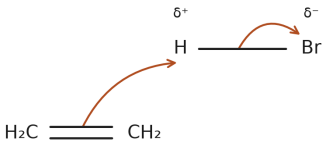


Propene → poly(propene); continuation bonds cross the brackets.
Side groups stay attached; no small molecule is eliminated.

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

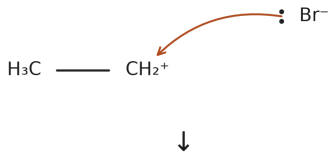
Ethene and HBr: follow both electron pairs

1 Form the ethyl carbocation



π pair → H; H–Br pair → Br

2 Bromide donates its lone pair



H3C–CH2–Br

bromoethane

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