Organic synthesis

A-Level Chemistry

Organic synthesis

This topic does not add new reactions. Instead it asks you to **join up** the reactions you already know, so you can build a target molecule in several steps.

Medicines are built up from simple starting materials by multi-step organic synthesis

Identifying functional groups

A molecule may have more than one **functional group** 官能团. Use the test reactions from the syllabus to identify each one, and then predict how the molecule will behave. For example:

- decolourises bromine water → a C=C double bond (an **alkene** 烯烃).
- gives a precipitate with silver nitrate → a **halogenoalkane** 卤代烷.
- orange $K_2Cr_2O_7$ turns green → a primary or secondary **alcohol** 醇.
- orange precipitate with 2,4-DNPH → an **aldehyde** 醛 or **ketone** 酮.
- fizzes with a carbonate → a **carboxylic acid** 羧酸.

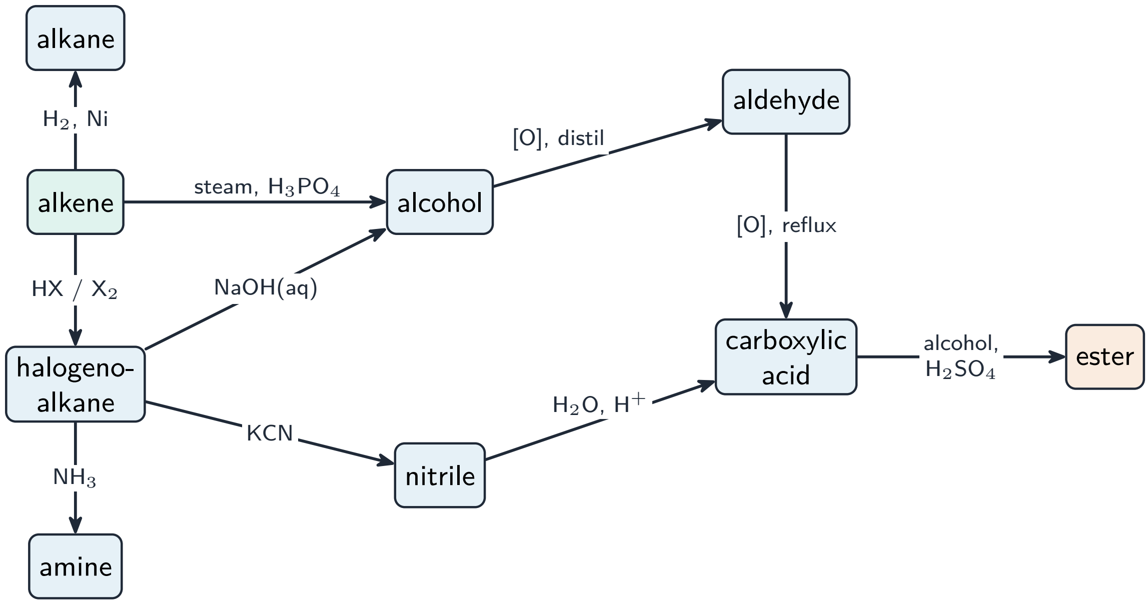
add this	you see	functional group
bromine water	orange → colourless	C=C (alkene)
silver nitrate	a precipitate forms	halogenoalkane
acidified $K_2Cr_2O_7$	orange → green	1°/2° alcohol
2,4-DNPH	orange precipitate	aldehyde / ketone
a carbonate	fizzes (CO_2 given off)	carboxylic acid

The standard identification tests: each reagent gives a characteristic observation that points to one functional group

A map of the AS reactions

Each row turns one functional group into another. Learn it as a map you can travel around:

Start	Reagent and conditions	Product
alkene	H_2, Ni	alkane
alkene	HX, or X_2	halogenoalkane
alkene	steam, H_3PO_4	alcohol
halogenoalkane	NaOH(aq), heat	alcohol
halogenoalkane	KCN in ethanol, heat	a **nitrile** 腈 (adds one carbon)
halogenoalkane	NH_3 in ethanol, pressure	an **amine** 胺
alcohol	$K_2Cr_2O_7$, distil / reflux	aldehyde / carboxylic acid
alcohol	concentrated acid, heat	alkene
aldehyde or ketone	$NaBH_4$	alcohol
aldehyde or ketone	HCN, KCN	hydroxynitrile
nitrile	dilute acid, heat	carboxylic acid
carboxylic acid + alcohol	concentrated H_2SO_4	an **ester** 酯



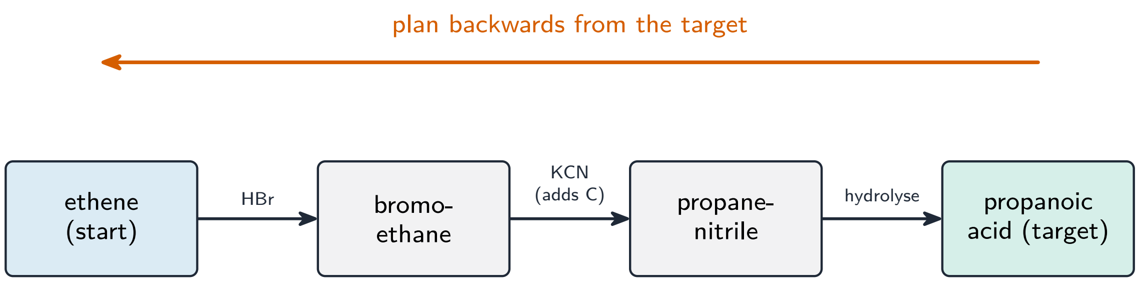
A map of the AS reactions: each arrow turns one functional group into another. Work backwards from your target to plan a route

Planning a multi-step route

To devise a **synthetic route** 合成路线:

1. compare the target with the starting material —what has changed (the functional group, the number of carbons)?
2. work **backwards** from the target: which single reaction could make it, and from what?
3. repeat until you reach the starting material.
4. write each step with its **reagent** 试剂 and conditions.

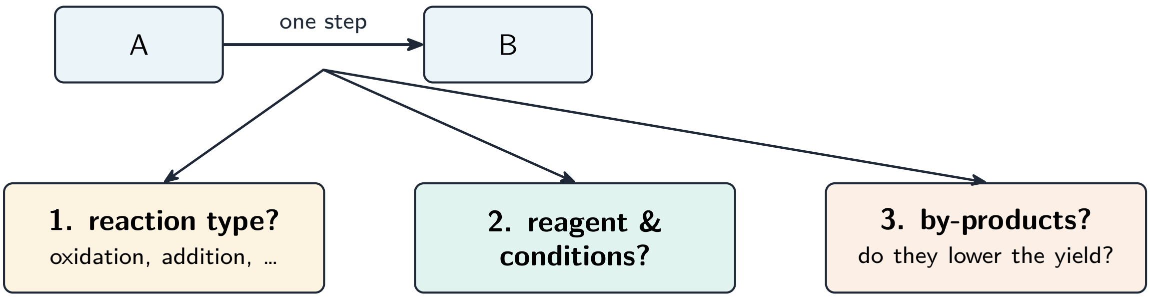
If you need to add a carbon, the KCN step is the key —it is the only AS reaction that lengthens the chain.



Plan a route by working backwards from the target, one reaction at a time, until you reach the starting material

Analysing a route

When you are given a route, for each step state the **type of reaction** (such as **oxidation** 氧化, **reduction** 还原, substitution, addition or elimination) and the reagent used. Also think about possible **by-products** 副产物—for example, making an amine from a halogenoalkane also gives a mixture of further-substituted amines, so the yield of the simple amine is low.



e.g. a halogenoalkane → amine also makes further-substituted amines, so the simple-amine yield is low

For every step in a given route, ask its reaction type, reagent and by-products

name the reaction type at each step

oxidation	loses electrons / gains O or loses H (e.g. alcohol → acid)
reduction	gains electrons / loses O or gains H
substitution	one atom or group swaps for another
addition	two molecules join; a C=C double bond opens
elimination	a small molecule is removed; a C=C forms

also give the **reagent** for each step, and watch for **by-products** (e.g. amines over-substitute)

Name the reaction type at each step: oxidation, reduction, substitution, addition or elimination

Worked example. Devise a route from propene to propanone, CH_3COCH_3. Work **backwards** from the target. A ketone comes from oxidising a **secondary** alcohol, so the step before propanone is propan-2-ol with acidified $K_2Cr_2O_7$ under reflux. Propan-2-ol comes from propene by adding **steam** over an H_3PO_4 catalyst - and Markovnikov's rule conveniently puts the OH on the **middle** carbon, which is exactly the secondary alcohol needed. So the route is: propene, then steam with H_3PO_4, giving propan-2-ol; then acidified $K_2Cr_2O_7$ under reflux, giving propanone. Give a **reagent and its conditions** on every arrow: a route with the right intermediates but no reagents scores very little.

Exam tips

- Learn the **reagents and conditions** for each conversion —that is exactly what synthesis questions test.
- Plan multi-step routes by functional group and watch the **carbon count** (KCN adds one carbon).
- Choose the **shortest valid route** and state every reagent and condition.