

Chemical identification AS to A2

An English reference for Pearson Edexcel International AS and A Level Chemistry (2018 specification, XCH11 / YCH11). Prepared for Mr. Tim's Chemistry Hub.

What this handbook covers

The identification methods and diagnostic observations across AS and A2: organic functional groups, gases, anions, flame tests, all eight metal ions in specification 17.22, ligand exchange, oxidation-state colours, IR, mass spectrometry, both NMR methods, chromatography and purity. Supporting tests are clearly marked where they go beyond an explicitly named test in the specification.

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Use the observation precisely

"An orange precipitate forms" and "the solution turns orange" describe different results. A positive 2,4-DNPH test forms a yellow/orange (sometimes red-orange) solid derivative. It is not a standard red-to-orange colour change.

Laboratory use: This is a revision reference, not a substitute for a teacher-approved practical procedure. Use fresh portions for separate tests, follow the stated conditions, and do not smell unknowns directly. Hazardous reagents and gases require the controls specified by your laboratory.

Edition: 10 October 2026. Original explanations and tables; not a Pearson publication. Use the data booklet and any conditions supplied in an examination question.

Choose the next useful test

Identify a functional group or ion first; establish a specific compound by combining independent evidence.

Starting clue	Useful next test	What you can conclude
An unknown organic liquid	$\text{NaHCO}_3(\text{aq})$, 2,4-DNPH and bromine water on separate portions	Screen for acidity, aldehyde/ketone and reactive unsaturation.
Positive 2,4-DNPH	Tollens' reagent; Fehling's where appropriate	Aldehyde versus ordinary ketone. Then use iodoform or spectra to narrow the structure.
Possible alcohol	Acidified dichromate(VI), then test the oxidation product	Primary/secondary alcohols oxidise; tertiary alcohols resist these conditions.
Colourless inorganic solution	Flame test, NaOH and NH_3 on separate portions	Use the pattern of precipitate colour and solubility, not just one white precipitate.
Possible halide or sulfate	Use the correct acid before AgNO_3 or BaCl_2	Remove interfering anions without adding the ion you are testing for.
An organic formula and spectra	Combine M_r , IR, NMR and chemical tests	Check that every atom and every observation fits one consistent structure.

The exam-answer template

Reagent: identify it completely, including the acid or alkali.

Conditions: add heat, warm water bath, room temperature, or excess where needed.

Observation: give the starting colour and final colour; state "precipitate", "solution", "gas" or "silver mirror".

Inference: state what the result supports and any remaining possibilities.

Negative evidence still matters

"No visible change" is a valid observation. State the unchanged reagent colour where useful. A negative result is meaningful only if the reagent works, enough sample is present, and the correct conditions and time are used.

Avoid cross-contamination: Acidify only the portion intended for that test. Hydrochloric acid introduces chloride; sulfuric acid introduces sulfate; ammonia introduces ammonium after acidification. Do not use one repeatedly treated tube for unrelated tests.

Alkenes and the -OH group

AS: distinguish a reaction with bromine from a general test for a reactive hydroxyl group.

C=C: bromine water

Reagent / conditions: add bromine water and shake at room temperature, away from strong UV light; no catalyst is needed.

Positive observation: orange/brown bromine water becomes colourless.

Inference: consistent with an alkene; bromine reacts across C=C.

Example: ethene + bromine → 1,2-dibromoethane (the simple bromine-addition model).

Limit: phenol, phenylamine and some reducing compounds also consume bromine. Combine the result with other evidence.

Alkane or benzene compared with an alkene

Under the same room-temperature test without UV or a halogen-carrier catalyst, a simple alkane and benzene do not rapidly decolourise bromine water. Alkane substitution in UV and benzene bromination with FeBr_3 are different conditions. Failure to decolourise alone does not prove either compound is present.

Oxidation of an alkene: manganate(VII)

Reagent / conditions: cold, dilute acidified potassium manganate(VII).

Observation: purple solution loses its colour as MnO_4^- is reduced to Mn^{2+} ; dilute Mn^{2+} appears colourless or very pale pink.

Inference: oxidation is taking place; under controlled mild conditions an alkene can form a diol.

Limit: many other reducing substances give this change. Brown MnO_2 indicates different or insufficiently acidic conditions; do not confuse the products.

PCl_5 : evidence for an -OH group

Reagent / conditions: phosphorus(V) chloride with a dry sample at room temperature, using an approved dry procedure.

Observation: steamy acidic fumes of HCl; a rod carrying ammonia gives white NH_4Cl fumes.

Example: $\text{ROH} + \text{PCl}_5 \rightarrow \text{RCl} + \text{POCl}_3 + \text{HCl}$.

Limit: water and carboxylic acids also react. This does not uniquely identify an alcohol, and it is unsuitable for an aqueous sample.

Sodium metal (supporting reaction): dry alcohols release H_2 , forming alkoxides: $2\text{ROH} + 2\text{Na} \rightarrow 2\text{RONa} + \text{H}_2$. Water, phenols and carboxylic acids also react, so effervescence is not alcohol-specific. Use only a supervised procedure.

Classify an alcohol by oxidation

AS: the product gives stronger evidence than the reagent colour alone.

Alcohol class	Acidified $K_2Cr_2O_7$, warm	Product and follow-up
Primary, RCH_2OH	Orange solution turns green.	Distil the aldehyde as it forms. It gives a positive Tollens' test. With excess oxidant under reflux, form a carboxylic acid.
Secondary, R_2CHOH	Orange solution turns green.	A ketone forms: positive 2,4-DNPH, normally negative Tollens'.
Tertiary, R_3COH	No orange-to-green change under ordinary laboratory oxidation conditions.	No oxidation product under these conditions; confirm the -OH group independently.

What changes colour?

Dichromate(VI), $Cr_2O_7^{2-}$, is orange; reduction produces green Cr^{3+} . Use dilute sulfuric acid to acidify the oxidant. The colour change reports oxidation of the sample; it does not by itself distinguish primary from secondary alcohols, and aldehydes also reduce this reagent.

Three standard examples

Propan-1-ol: $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$. Distillation helps collect propanal before further oxidation.

Further oxidation: $CH_3CH_2CHO + [O] \rightarrow CH_3CH_2COOH$. Reflux with excess oxidant gives propanoic acid.

Propan-2-ol: $CH_3CH(OH)CH_3 + [O] \rightarrow CH_3COCH_3 + H_2O$. The product is propanone.

Use the product tests on suitable separated samples

Distillation or other appropriate separation prevents leftover acidic oxidant from confusing later tests. Sodium hydrogencarbonate added directly to an acidified reaction mixture will fizz because the reagent already contains acid; that alone does not prove an organic acid was produced.

Fast distinction: propan-1-ol and propan-2-ol both turn acidified dichromate from orange to green. A simpler separate test is iodoform: propan-2-ol gives a yellow precipitate; propan-1-ol does not. See page 6 for the exact structural requirement.

Aldehydes and ketones

A2: detect the carbonyl type, then distinguish aldehyde from ketone.

Test and conditions	Positive observation	Meaning and limitations
2,4-DNPH / Brady's reagent; add to the sample and mix.	A yellow/orange precipitate forms; some derivatives are red-orange.	Aldehyde or ketone. Carboxylic acids, esters and amides do not normally give this test, although they also contain C=O.
Tollens' reagent (fresh ammoniacal silver nitrate); warm gently in a water bath.	A silver mirror or grey/black silver deposit.	An aldehyde reduces Ag(I) to Ag. Ordinary ketones are negative. Other reducing substances can also react.
Fehling's solution (freshly mixed alkaline Cu(II) complex); warm.	Blue solution gives a brick-red Cu ₂ O precipitate.	Usually a positive result for aliphatic aldehydes. Ordinary ketones are negative; aromatic aldehydes are not reliably positive.
Benedict's solution; warm.	Blue reagent forms a brick-red/orange Cu ₂ O precipitate, with appearance affected by amount.	Alternative Cu(II) reduction test for suitable aldehydes and reducing sugars; not a unique proof of an aldehyde in any mixture.
Acidified K ₂ Cr ₂ O ₇ ; warm.	Orange solution becomes green.	Aldehydes oxidise to carboxylic acids; ordinary ketones resist these conditions. Primary/secondary alcohols also react.

The decision

DNPH positive + Tollens' positive: consistent with an aldehyde.

DNPH positive + Tollens' negative: consistent with an ordinary ketone.

DNPH negative: do not conclude that no C=O bond exists; an ester or carboxylic acid could be present.

Useful equations: $\text{RCHO} + [\text{O}] \rightarrow \text{RCOOH}$. In alkaline Tollens' reagent: $\text{RCHO} + 2[\text{Ag}(\text{NH}_3)_2]^+ + 3\text{OH}^- \rightarrow \text{RCOO}^- + 2\text{Ag} + 4\text{NH}_3 + 2\text{H}_2\text{O}$.

Handling: Tollens' reagent is prepared fresh and disposed of promptly by the approved laboratory procedure; never store it or let residues dry. DNPH must be kept in its approved wetted/reagent form.

Iodoform and derivative identification

A2: learn the substructure, not just a list of positive compounds.

The iodoform test

Reagent / conditions: iodine in aqueous alkali (usually NaOH); warm gently if required.

Positive observation: a pale-yellow/yellow precipitate of triiodomethane, CHI_3 , forms.

Directly positive group: $\text{CH}_3\text{CO}-$ in a methyl ketone; ethanal is also positive.

Also positive: alcohols containing $\text{CH}_3\text{CH}(\text{OH})-$, because oxidation produces the required carbonyl group. Ethanol is positive because it forms ethanal.

Positive examples	Negative examples	Reason
Ethanal	Propanal	Only ethanal has the required methyl arrangement among the simple aldehydes.
Propanone; butan-2-one	Pentan-3-one	A methyl ketone has CH_3 directly attached to $\text{C}=\text{O}$.
Ethanol; propan-2-ol; butan-2-ol	Methanol; propan-1-ol; 2-methylpropan-2-ol	The alcohol must oxidise to ethanal or a methyl ketone.

Equation for a methyl ketone:



Common error: iodine losing its brown colour alone is not the positive iodoform observation. State the yellow precipitate. A methyl group anywhere in a molecule is not sufficient.

Identify a specific aldehyde or ketone with its DNPH derivative

Form the solid 2,4-dinitrophenylhydrazone; isolate and purify it by the prescribed method, then measure its melting range. Compare with reference melting temperatures supplied for candidate derivatives. A close match supports the identity when the derivative is pure; mixed or impure products can give a depressed, broadened range.

How the evidence combines

An unknown gives DNPH, Tollens' and iodoform positives. Among simple monofunctional aldehydes, ethanal fits. If Tollens' is negative but iodoform is positive, look for a methyl ketone and use M_r or NMR to determine the rest of the molecule.

Acids, esters and acyl chlorides

AS to A2: distinguish gas evolution, rapid hydrolysis and slower hydrolysis.

Carboxylic acid: carbonate / hydrogencarbonate

Reagent / conditions: add aqueous sodium carbonate or sodium hydrogencarbonate at room temperature.

Observation: effervescence; the released CO_2 turns limewater milky.

Equation: $\text{RCOOH} + \text{NaHCO}_3 \rightarrow \text{RCOONa} + \text{CO}_2 + \text{H}_2\text{O}$.

Limit: other acids also release CO_2 . This distinguishes a typical carboxylic acid from an alcohol or phenol within a known organic set; use IR to support the carboxyl group.

Acyl chloride: reaction with water

Conditions: a teacher-approved small-scale addition to water at room temperature.

Observation: rapid/exothermic hydrolysis; HCl is formed, often seen as steamy fumes in moist air. An insoluble product may appear if the acid is poorly soluble.

Equation: $\text{RCOCl} + \text{H}_2\text{O} \rightarrow \text{RCOOH} + \text{HCl}$.

Confirmation: the aqueous hydrolysate contains Cl^- ; acidify a suitable separate portion with HNO_3 and add AgNO_3 for white AgCl .

Limit: water solubility and speed vary; the carbonyl signal and full evidence are required.

Ester: hydrolysis and product identification

Reagent / conditions: heat with dilute acid under reflux, or reflux with aqueous NaOH .

Result: acid hydrolysis gives a carboxylic acid and alcohol; alkaline hydrolysis gives a carboxylate salt and alcohol.

Equation: $\text{RCOOR}' + \text{OH}^- \rightarrow \text{RCOO}^- + \text{R}'\text{OH}$.

Evidence: identify separated products and combine with ester C=O / C-O IR signals. There is no universal unique visible colour test. Odour alone is not reliable evidence.

Amide and acid anhydride: avoid false carbonyl conclusions

Amides contain C=O but normally do not give DNPH. Identify using their IR and hydrolysis evidence (page 9). Acid anhydrides, where supplied in a question or data booklet, hydrolyse to carboxylic acids and often show two C=O absorptions; include them when interpreting unfamiliar spectral data.

Acyl chloride + ammonia: formation of an amide and NH_4Cl is vigorous and can produce white fumes/solid. It is a diagnostic reaction within a known set, not a safe unsupervised screening test.

Phenols and amines

A2: activated aromatic rings and nitrogen bases give overlapping but useful evidence.

Phenol + bromine water

Conditions: add bromine water at room temperature, without a catalyst.

Observation: bromine water decolourises and a white precipitate of 2,4,6-tribromophenol forms.

Equation: $\text{C}_6\text{H}_5\text{OH} + 3\text{Br}_2 \rightarrow \text{C}_6\text{H}_2\text{Br}_3\text{OH} + 3\text{HBr}$.

Distinction: a simple alkene decolourises bromine water but normally does not give this characteristic white solid. Phenylamine can give a similar result, so use other evidence.

Phenol: supporting Fe(III) and acid-base tests

Neutral $\text{FeCl}_3(\text{aq})$: phenol typically gives a violet/purple solution. Some substituted phenols produce other colours; this is a supporting test, not the uniquely specified phenol test in the IAL syllabus.

$\text{NaOH}(\text{aq})$: phenol forms soluble phenoxide; an insoluble sample may dissolve.

$\text{NaHCO}_3(\text{aq})$: ordinary phenol gives no CO_2 effervescence, unlike a carboxylic acid. Other substituents can alter acidity.

Amines: basicity and salt formation

A water-soluble aliphatic amine gives an alkaline solution and turns damp red litmus blue. Dilute acid produces an ammonium salt; a poorly water-soluble amine may dissolve. Adding alkali to the salt can regenerate the amine.

Equation: $\text{RNH}_2 + \text{H}^+ \rightarrow \text{RNH}_3^+$.

Limit: ammonia and other bases behave similarly. Aromatic amines are weaker bases, and low solubility makes a litmus test less decisive.

Primary aromatic amine: diazotisation and coupling

Conditions: NaNO_2 with dilute HCl at $0-5^\circ\text{C}$ forms the diazonium salt; then couple with phenol in alkaline conditions, following the approved procedure.

Observation: an intensely coloured azo dye forms; the hue depends on the reactants (often orange/red).

Inference: supports a primary aromatic amino group in the appropriate candidate set. Do not describe this as one universal colour for all amines.

Other specified amine evidence: primary amines act as ligands toward Cu^{2+} and may produce a deep-blue complex; the appearance depends on the amine and conditions. It is not unique to amines because excess NH_3 gives similar copper complexation.

Amides, nitriles and biomolecules

A2: some functional groups require chemical conversion or instrumental evidence.

Target	Useful evidence	Interpretation / limit
Primary amide, RCONH_2	Heat with aqueous NaOH; test the evolved gas with damp red litmus.	NH_3 turns litmus blue. $\text{RCONH}_2 + \text{OH}^- \rightarrow \text{RCOO}^- + \text{NH}_3$. N-substituted amides can release amines instead.
Nitrile, RCN	$\text{C}\equiv\text{N}$ IR absorption; hydrolysis under reflux with dilute acid or alkali.	Hydrolysis produces a carboxylic acid/carboxylate plus ammonium/ammonia. No single universal visible room-temperature test.
Amino acid	Both acid and base reactions; zwitterion behaviour; NMR/IR and formula.	Acidic and basic groups coexist. Most chiral amino acids rotate plane-polarised light as pure enantiomers; glycine is achiral.
Protein / peptide (supporting test)	Biuret: alkaline solution with a small amount of CuSO_4 .	Lilac/violet solution supports multiple peptide bonds. A free amino acid does not give the same positive test.
Amino acids (supporting test)	Ninhydrin, usually with warming or as a chromatogram stain.	Many amino acids form purple colour; proline is a notable yellow exception. Other amino compounds can react.
Nitro compound	Characteristic pair of strong NO_2 IR bands and compatible formula; reduction then test the product.	An aromatic nitro compound reduced with Sn/HCl yields an aromatic ammonium salt; add alkali to release the amine.

Amide compared with amine

An amide nitrogen lone pair is delocalised towards $\text{C}=\text{O}$, so amides are much less basic. Do not label an unknown "amine" just because it contains nitrogen. Use the $\text{C}=\text{O}$ evidence and hydrolysis products; primary/secondary amides can have N-H absorptions.

Hydrolysis is not always a single visible test

Nitriles and primary amides can both release ammonia on alkaline hydrolysis. Distinguish them by $\text{C}\equiv\text{N}$ versus $\text{C}=\text{O}$ in IR and the rest of the data. Also test a fresh portion for pre-existing NH_4^+ before using ammonia evolution to infer a covalent nitrogen group.

Scope: biuret and ninhydrin are included as useful supporting identification methods; they are not separate mandatory named tests in the 2018 IAL specification. For polymers, combine the repeat-unit chemistry, hydrolysis products and IR.

Halide ions and halogenoalkanes

AS: first decide whether the halogen is already an ion or is covalently bonded.

Ion	AgNO ₃ after dilute HNO ₃	Dilute NH ₃	Concentrated NH ₃
Cl ⁻	White AgCl precipitate	Dissolves	Dissolves
Br ⁻	Cream AgBr precipitate	Does not dissolve appreciably	Dissolves
I ⁻	Yellow AgI precipitate	Insoluble	Insoluble

Aqueous halide: correct order

Acidify the sample with dilute nitric acid, then add aqueous silver nitrate. The acid removes interfering carbonate/hydroxide species; do not acidify with HCl because it introduces chloride. Add ammonia to the precipitate on the prescribed scale to distinguish the silver halides.

Equations: $\text{Ag}^+ + \text{X}^- \rightarrow \text{AgX(s)}$; $\text{AgCl} + 2\text{NH}_3 \rightleftharpoons [\text{Ag}(\text{NH}_3)_2]^+ + \text{Cl}^-$.

Covalently bonded halogen: release the halide first

Hydrolysis route: warm the halogenoalkane with aqueous NaOH (ethanol may assist mixing). Cool, acidify with dilute HNO₃ to neutralise remaining OH⁻, then add AgNO₃. The precipitate identifies the released halide.

Hydrolysis equation: $\text{RX} + \text{OH}^- \rightarrow \text{ROH} + \text{X}^-$.

Reason: the original C-X bond does not supply free halide ions simply by dissolving the compound.

The AS rates practical: aqueous AgNO₃ in ethanol

Warm comparable halogenoalkanes with aqueous silver nitrate in ethanol at a controlled temperature. Record the time to precipitate. Halide released by hydrolysis precipitates as AgX. With comparable structures, iodoalkanes normally react fastest and chloroalkanes slowest because the C-I bond is weakest. Use equal concentrations, temperature and volumes for a fair comparison.

Exceptions: fluoroalkanes are resistant to ordinary hydrolysis and AgF is soluble. Halogenoarenes are much less reactive than analogous halogenoalkanes under these conditions. A negative AgNO₃ result is not proof that a molecule contains no halogen.

Anions and ammonium

AS core tests first; additional familiar tests are labelled as supporting methods.

Target	Reagent and conditions	Positive observation / equation
CO_3^{2-} or HCO_3^-	Add dilute acid; pass gas into limewater.	Effervescence; limewater turns milky. $\text{CO}_3^{2-} + 2\text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{O}$; $\text{HCO}_3^- + \text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{O}$.
SO_4^{2-}	Acidify with dilute HCl; add $\text{BaCl}_2(\text{aq})$.	White BaSO_4 precipitate, remaining in dilute acid. $\text{Ba}^{2+} + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4(\text{s})$.
NH_4^+	Add $\text{NaOH}(\text{aq})$, warm gently; test gas at the mouth of the tube.	NH_3 turns damp red litmus blue; forms white fumes with HCl. $\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$.
NO_3^- (supporting)	Warm with aqueous NaOH and aluminium or Devarda's alloy, under an approved procedure.	Reduction produces NH_3 . Check for original NH_4^+ on a fresh portion first; nitrite can interfere.
SO_3^{2-} (supporting)	Add dilute acid; test gas with acidified dichromate or manganate(VII).	SO_2 evolves and reduces orange dichromate to green or decolourises purple manganate(VII).
$\text{S}_2\text{O}_3^{2-}$ (supporting)	Add dilute acid.	Cloudiness/yellow sulfur and SO_2 . $\text{S}_2\text{O}_3^{2-} + 2\text{H}^+ \rightarrow \text{S} + \text{SO}_2 + \text{H}_2\text{O}$.
S^{2-} (supporting)	Only in a specified supervised procedure: dilute acid and a suitable gas test.	H_2S may be released; damp lead(II) ethanoate paper blackens. Do not use odour as a test.

Do not contaminate the anion test

Use HCl for the standard BaCl_2 sulfate test, not sulfuric acid. Nitric acid and barium nitrate are an alternative compatible pair. For AgNO_3 halide tests use nitric acid, not hydrochloric acid. Acidification suppresses some competing precipitates; record the required order.

Carbonate versus hydrogencarbonate: the acid/limewater test detects both and does not distinguish them. Use additional supplied data, quantitative acid consumption or a suitable specified procedure to tell them apart.

Gases and water

Write the observation of the confirming test, not only “a gas is produced”.

Gas / substance	Test	Positive observation and caution
Hydrogen, H ₂	A lighted splint at the mouth of a small collected sample.	A squeaky pop. Never ignite a closed vessel or a large unknown gas mixture.
Oxygen, O ₂	Insert a glowing splint.	The glowing splint relights.
Carbon dioxide, CO ₂	Bubble through limewater, Ca(OH) ₂ (aq).	Milky white CaCO ₃ precipitate. Excess CO ₂ can dissolve it as soluble hydrogencarbonate.
Ammonia, NH ₃	Damp red litmus; separate confirmation with HCl fumes.	Litmus turns blue; white NH ₄ Cl fumes form with HCl.
Chlorine, Cl ₂	Damp blue litmus / moist indicator paper.	Turns red then bleaches white; pale green gas. Bleaching requires moisture.
Hydrogen chloride, HCl	Damp blue litmus; ammonia near the gas.	Litmus turns red; white NH ₄ Cl fumes with NH ₃ . Many acidic gases redden litmus.
Sulfur dioxide, SO ₂	Acidified K ₂ Cr ₂ O ₇ paper/solution or acidified KMnO ₄ .	Orange to green or purple to colourless. Confirms reducing behaviour; not unique by itself.
Nitrogen dioxide, NO ₂	Recognise supplied observations.	Brown gas; acidic when dissolved in water. Do not deliberately inhale.
Hydrogen sulfide, H ₂ S (supporting)	Damp lead(II) ethanoate paper in a supervised test.	Black PbS forms. Toxic gas; smell is not a valid practical test.
Water	Anhydrous CuSO ₄ or dry cobalt chloride paper.	White CuSO ₄ turns blue; blue cobalt chloride paper turns pink.

Limewater: $\text{CO}_2 + \text{Ca(OH)}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}$. With excess CO₂: $\text{CaCO}_3 + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{Ca(HCO}_3)_2$.

Presence versus purity: a positive water test shows water is present. It does not show pure water. A sharp boiling point near 100 °C at 1 atm, alongside other evidence, can support purity. Nitrogen and carbon monoxide have no simple unique school-level splint test; interpret any method or instrument supplied.

Flames, halogens and solid halides

AS: recognise the colours and the conditions that produce them.

Flame-test ion	Expected colour	Flame-test ion	Expected colour
Li^+	Crimson red	Na^+	Strong yellow
K^+	Lilac	Ca^{2+}	Brick red / orange-red
Sr^{2+}	Crimson / scarlet red	Ba^{2+}	Apple green
Cu^{2+} (supporting)	Blue-green	Mg^{2+}	No characteristic visible flame colour

Use a clean wire loop or an approved clean-splint method in a non-luminous flame. Sodium contamination can mask another colour. A coloured flame is evidence for a metal species, not for its accompanying anion. Burning magnesium metal with a white flame is different from a Mg^{2+} salt flame test.

Halogen	Element at room conditions	Aqueous solution	Non-polar solvent
Cl_2	Pale green gas	Pale green / yellow-green	Pale green
Br_2	Red-brown liquid	Orange / orange-brown	Orange / red-brown
I_2	Grey-black solid; purple vapour on heating	Brown	Purple / violet

Displacement: Cl_2 liberates Br_2 from Br^- and I_2 from I^- ; Br_2 liberates I_2 from I^- ; I_2 does neither. Example: $\text{Cl}_2 + 2\text{Br}^- \rightarrow 2\text{Cl}^- + \text{Br}_2$. Use the new halogen colour, ideally in the specified organic layer, to identify the product.

Solid salt + concentrated H_2SO_4	Diagnostic observations
Chloride	Steamy HCl fumes; no halogen redox product in the usual test.
Bromide	HBr fumes and orange/brown bromine; SO_2 also forms.
Iodide	Purple iodine vapour / dark iodine, possibly yellow sulfur and H_2S ; several reduction products may form.

Thermal decomposition clues: many Group 2 nitrates give brown NO_2 and O_2 ; Group 2 carbonates give CO_2 . These gas tests identify the products, but the metal still needs independent identification. Concentrated-acid and toxic-gas observations belong to controlled practicals or supplied exam data.

Metal ions with sodium hydroxide

A2 specification 17.22: Cr^{3+} , Mn^{2+} , Fe^{2+} , Fe^{3+} , Co^{2+} , Ni^{2+} , Cu^{2+} and Zn^{2+} are all included.

Ion / usual aqueous colour	NaOH, a few drops	NaOH, excess
Cr^{3+} : green or violet, depending on ligands	Grey-green / green $\text{Cr}(\text{OH})_3$ precipitate	Dissolves to a green hydroxo complex in sufficient excess.
Mn^{2+} : very pale pink	Off-white / pale buff $\text{Mn}(\text{OH})_2$ precipitate; browns on standing in air	Insoluble; oxidation by air changes its colour.
Fe^{2+} : pale green	Green $\text{Fe}(\text{OH})_2$ precipitate; gradually browns in air	Insoluble.
Fe^{3+} : yellow/brown in typical solutions	Red-brown $\text{Fe}(\text{OH})_3$ precipitate	Insoluble.
Co^{2+} : pink	Blue $\text{Co}(\text{OH})_2$ precipitate, often pinker on standing; may darken in air	Insoluble.
Ni^{2+} : green	Green $\text{Ni}(\text{OH})_2$ precipitate	Insoluble.
Cu^{2+} : pale blue	Pale-blue $\text{Cu}(\text{OH})_2$ precipitate	Insoluble.
Zn^{2+} : colourless	White $\text{Zn}(\text{OH})_2$ precipitate	Dissolves to a colourless solution.
Al^{3+} : colourless (supporting)	White $\text{Al}(\text{OH})_3$ precipitate	Dissolves to a colourless solution.
Mg^{2+} : colourless (supporting)	White $\text{Mg}(\text{OH})_2$ precipitate	Insoluble.
Ca^{2+} : colourless (supporting)	White $\text{Ca}(\text{OH})_2$ precipitate if concentrated enough	Insoluble in excess; a dilute solution may give little precipitate.

Precipitation: $\text{M}^{2+} + 2\text{OH}^- \rightarrow \text{M}(\text{OH})_2(\text{s})$; $\text{M}^{3+} + 3\text{OH}^- \rightarrow \text{M}(\text{OH})_3(\text{s})$. These are simplified ionic forms. Include coordinated waters if requested in an A2 complex-ion equation.

Amphoteric examples: $\text{Zn}(\text{OH})_2 + 2\text{OH}^- \rightarrow [\text{Zn}(\text{OH})_4]^{2-}$; $\text{Al}(\text{OH})_3 + \text{OH}^- \rightarrow [\text{Al}(\text{OH})_4]^-$. Chromium(III) forms soluble hydroxo species in excess alkali; the simplified fully hydroxylated representation is $[\text{Cr}(\text{OH})_6]^{3-}$.

Observe immediately and on standing. Air oxidation explains why Fe^{2+} and Mn^{2+} precipitates change colour. Record "precipitate dissolves to a ... solution", not simply "turns colourless".

Metal ions with aqueous ammonia

Add a few drops first, then an actual excess; these are two different observations.

Ion	NH ₃ (aq), a few drops	NH ₃ (aq), excess
Cr ³⁺	Grey-green / green hydroxide precipitate	Normally insoluble in the routine test; slow changes under special conditions are not the standard observation.
Mn ²⁺	Off-white / buff hydroxide precipitate, browning in air	Insoluble.
Fe ²⁺	Green hydroxide precipitate; browns in air	Insoluble.
Fe ³⁺	Red-brown hydroxide precipitate	Insoluble.
Co ²⁺	Blue/green hydroxide precipitate may form initially	Dissolves to a straw/yellow-brown ammine solution; darkens/browns as oxygen oxidises Co(II).
Ni ²⁺	Green hydroxide precipitate	Dissolves to a blue/violet ammine solution, [Ni(NH ₃) ₆] ²⁺ .
Cu ²⁺	Pale-blue hydroxide precipitate	Dissolves to a deep-blue solution, [Cu(NH ₃) ₄ (H ₂ O) ₂] ²⁺ .
Zn ²⁺	White hydroxide precipitate	Dissolves to colourless [Zn(NH ₃) ₄] ²⁺ .
Al ³⁺ (supporting)	White hydroxide precipitate	Insoluble.
Mg ²⁺ (supporting)	White hydroxide precipitate	Insoluble.
Ca ²⁺ (supporting)	Usually no precipitate, or only a slight precipitate	No significant change.

Why ammonia can do two jobs

As a base: $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$. Hydroxide ions cause precipitation; NH₃ is not part of a metal-hydroxide lattice.

As a ligand: excess NH₃ forms soluble ammine complexes for suitable ions. Copper is the clearest example: the pale-blue solid dissolves into a deep-blue solution.

Distinguishing white precipitates: Zn²⁺ dissolves in excess NaOH and excess NH₃. Al³⁺ dissolves in excess NaOH but not excess NH₃. Mg²⁺ dissolves in neither. Confirm Ca²⁺ with its flame and weak/no precipitation with NH₃. Colours and completeness of dissolution depend on concentration and time.

Ligand exchange and redox colours

A2: a colour change can mean a new ligand, a new oxidation state, or an acid-base equilibrium.

System / change	Observation	Explanation
$\text{Cu}^{2+}(\text{aq}) + \text{excess NH}_3$	Pale-blue solution → pale-blue precipitate → deep-blue solution	Base reaction first, then ammine complex formation.
$\text{Cu}^{2+}(\text{aq}) + \text{concentrated HCl} / \text{excess Cl}^-$	Blue → green/yellow mixture; $[\text{CuCl}_4]^{2-}$ is yellow	Ligand exchange. Adding water favours the blue aqua complex again.
$\text{Co}^{2+}(\text{aq}) + \text{excess Cl}^-$	Pink → blue; water restores pink	$[\text{Co}(\text{H}_2\text{O})_6]^{2+} \rightleftharpoons [\text{CoCl}_4]^{2-}$ with ligand exchange.
$\text{Cr}_2\text{O}_7^{2-} + \text{OH}^-$; then acid	Orange → yellow; acid restores orange	Dichromate/chromate equilibrium; Cr remains +6.
$\text{Cr}_2\text{O}_7^{2-} + \text{Zn} / \text{acid}$	Orange → green Cr^{3+} → blue Cr^{2+}	Reduction; exclude air to preserve Cr^{2+} .
$\text{Cr}^{3+} + \text{H}_2\text{O}_2$ in alkali; then acidify	Green → yellow chromate; acid gives orange dichromate	Oxidation of Cr(III) to Cr(VI).
Acidified MnO_4^- + reducing agent	Purple → colourless / very pale pink	$\text{Mn(VII)} \rightarrow \text{Mn(II)}$. Brown MnO_2 signals other conditions.

Vanadium oxidation state	Species in acidic solution	Typical colour
+5	VO_2^+	Yellow
+4	VO^{2+}	Blue
+3	V^{3+}	Green
+2	V^{2+}	Violet

Reduction with zinc in acid can show yellow → blue → green → violet. An early green mixture of yellow V(V) and blue V(IV) does not by itself prove V(III); use the sequence and conditions.

Additional useful reactions: Fe^{3+} oxidises I^- to brown iodine and becomes Fe^{2+} . Cu^{2+} with I^- gives white CuI plus brown iodine, which may obscure the precipitate. These are redox observations, not NaOH tests.

Indicators and redox test reagents

AS to A2: distinguish an identification observation from a titration end point.

Reagent / system	Observation	What it shows
Iodine with starch	Blue-black colour when iodine/triiodide is present.	Sensitive evidence for iodine; iodide alone does not give this colour.
Iodine titrated with thiosulfate	Brown iodine becomes pale yellow; add starch near the end, then blue-black disappears.	End point: disappearance of iodine. $I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$.
Acidified $KMnO_4$ as titrant	Each purple drop initially decolourises; first permanent pale pink marks the end point.	A slight excess of MnO_4^- remains once the reducing agent is consumed; no separate indicator is needed.
Acidified dichromate(VI)	Orange to green with a suitable reducing substance.	$Cr(VI)$ is reduced to $Cr(III)$. This is a redox screen, not a unique functional-group identification.
KI solution, then starch	Brown iodine / blue-black with starch after oxidation of I^- .	Evidence for an oxidising agent; several different oxidants produce the same result.
$Fe^{3+} + SCN^-$ (supporting)	Blood-red solution of a thiocyanatoiron(III) complex.	Supports $Fe(III)$; competing ligands and conditions affect the response.

Acid-base indicator	Acid side	Alkaline side
Litmus	Red	Blue
Methyl orange	Red (orange in transition range)	Yellow
Phenolphthalein	Colourless	Pink
Universal indicator	Red/orange/yellow, depending on pH	Blue/purple; green near neutral

End points are not universal identity tests

Choose an indicator whose transition range lies within the steep part of the titration curve. An acid changes an indicator, but the colour does not uniquely identify that acid. In a weak-acid/strong-base titration, phenolphthalein is usually suitable; methyl orange is usually unsuitable.

Hydrogen peroxide: decomposition catalysed by MnO_2 produces O_2 that relights a glowing splint: $2H_2O_2 \rightarrow 2H_2O + O_2$. This supports peroxide in a known candidate set; H_2O_2 can act as either an oxidising or reducing agent, depending on its reaction partner.

IR: identify bonds and groups

AS to A2: use the combination of bands. The fingerprint region can support a reference match.

Group / bond	Useful region / cm^{-1}	What to look for
Alcohol / phenol O-H	3750-3200	Usually broad in hydrogen-bonded samples; overlaps N-H.
Carboxylic acid O-H	3300-2500	Very broad absorption, together with C=O.
Amine N-H	3500-3300	Primary amines often show two stretches; secondary one; tertiary none.
Amide N-H	3500-3140	Combine with amide C=O; absence is possible in N,N-disubstituted amides.
Alkane C-H	2962-2853	Common and not enough to identify an alkane uniquely.
Alkene C-H / C=C	3095-3010 / 1669-1645	Use both where visible; C=C may be weak.
Arene	C-H near 3030; ring bands near 1600 and 1500	Combine with aromatic NMR evidence.
Aldehyde	C=O 1740-1720; C-H near 2900-2820 and 2775-2700	Aldehyde C-H bands can be weak; confirm with chemical tests.
Alkyl ketone	C=O 1720-1700	Strong carbonyl band; ordinary ketone gives no Tollens' reaction.
Carboxylic acid	C=O 1725-1700 (alkyl)	C=O plus very broad acid O-H is the useful combination.
Ester	C=O 1750-1735 (saturated)	C-O bands support it; no acid O-H in a simple ester.
Acyl chloride / amide	C=O near 1795 / 1700-1630	Carbonyl position helps distinguish derivatives.
Nitrile / alkyne	C≡N 2260-2215 / C≡C 2260-2100	C≡N is often strong; some C≡C bands are weak or absent.

Interpretation rule: these are reference ranges, not exact boundaries. Conjugation, hydrogen bonding and the sample conditions shift peaks. Use the data given in the exam; a C=O absorption alone cannot identify a particular carbonyl family. C-X bands occur in the fingerprint region and need supplied/reference data.

Proton NMR: identify the H environment

A2: chemical shift, integration and splitting answer three different questions.

Protons being observed	Approximate δ / ppm	Interpretation
Alkyl H-C-C	0.7-2.0	Hydrogens bonded to ordinary saturated carbon.
H-C-C=O or near an arene	About 2-3	Hydrogens on carbon next to a carbonyl or aromatic system.
H-C-O or H-C-halogen	Commonly 3-4.5; varies with halogen	The observed H is attached to carbon, not directly to oxygen.
H-C=C	About 4.5-6.5	Vinyl H directly on the double-bonded carbon.
Ar-H	About 6-9	H directly attached to an aromatic ring.
-CHO	About 9-10	Aldehyde H attached to the carbonyl carbon.
-COOH	About 10-13, variable	Acidic O-H, often broad.
Alcohol/phenol O-H; N-H	Variable; strongly affected by conditions	Exchangeable; D ₂ O can remove the corresponding signal.

Read the spectrum in four steps

1. Count chemically different H environments, considering symmetry.
2. Match chemical shifts to plausible environments.
3. Use integration ratios for the numbers of H in those environments.
4. Use splitting to infer neighbouring non-equivalent H. For one set of n equivalent neighbouring H with the same coupling, expect n + 1 lines.

Splitting key: 0 neighbours: singlet (1); 1 neighbour: doublet (1 : 1); 2 neighbours: triplet (1 : 2 : 1); 3 neighbours: quartet (1 : 3 : 3 : 1).

Ethyl example: CH₃CH₂- often gives a 3H triplet and 2H quartet. The quartet represents 2 H in total, not 4 H. Equivalent protons do not split each other; different neighbour sets can give more complex patterns. Exchangeable O-H/N-H often do not show reliable n + 1 coupling.

D₂O test: O-H/N-H signals may disappear through exchange with deuterium. This supports an exchangeable proton but does not distinguish alcohol, acid, phenol and amine by itself. TMS is the 0 ppm reference.

Carbon NMR and mass spectrometry

A2: count carbon environments, establish a molecular mass, then test a proposed structure.

¹³ C environment	Approximate δ / ppm	Use
Saturated C-C	About 0-60	Ordinary alkyl carbon; overlap with other categories.
C bonded to O / N / halogen	Often about 30-90	Deshielded saturated carbon; the range depends strongly on the attached atom.
Alkene / arene carbon	About 100-160	Unsaturated carbon; use other evidence to distinguish.
Acid / ester / amide C=O	About 160-185	Carbonyl in a carboxylic acid derivative.
Aldehyde / ketone C=O	About 190-220	Strong evidence for this carbonyl family.

In a routine proton-decoupled ¹³C spectrum, count distinct carbon environments rather than applying the proton n + 1 rule. Symmetry reduces signal count. Peak heights/areas are not normally used as a direct carbon-number ratio. Use the supplied chemical-shift data for exact interpretation.

Molecular ion and accurate mass

In electron-ionisation mass spectrometry, a singly charged molecular ion M⁺• has m/z approximately equal to the relative molecular mass. It can be weak or absent. The base peak is simply the most intense peak, not necessarily the molecular ion. Accurate mass helps distinguish molecular formulae with the same nominal mass.

Mass-spectrum clue	What it supports
One Cl atom: M and M+2 about 3 : 1	Chlorine isotope pattern.
One Br atom: M and M+2 about 1 : 1	Bromine isotope pattern.
Two Cl atoms: M : M+2 : M+4 about 9 : 6 : 1	Two chlorine atoms, using approximate isotope abundances.
Two Br atoms: M : M+2 : M+4 about 1 : 2 : 1	Two bromine atoms.
Fragments such as m/z 43, 29 or 31	Candidate ions include CH ₃ CO ⁺ , C ₂ H ₅ ⁺ or CH ₂ OH ⁺ respectively; nominal masses are not unique.

Example: C₃H₆O has M_r = 58. Both propanal and propanone fit. A positive Tollens' test and an aldehyde proton near 9-10 ppm support propanal; a 6H singlet and negative Tollens' support propanone.

Chromatography, purity and formulae

AS to A2: identification becomes stronger when chemical and physical evidence agree.

Paper chromatography and TLC

Compare the unknown with reference samples on the same stationary phase and with the same solvent. Draw the baseline in pencil and keep it above the solvent. Mark the solvent front promptly.

R_f = distance travelled by the centre of the spot / distance travelled by the solvent front, measured from the same baseline.

A matching R_f supports an identity, but different compounds can share one value. Several spots suggest a mixture; one spot does not prove purity because components may co-elute or be invisible.

GC and HPLC

Compare retention times only under the same column, mobile-phase and operating conditions. Matching retention time supports but does not uniquely establish identity. A resolved peak count is a minimum number of detected components. Detector response and calibration matter when using peak areas to estimate amounts. GC-MS combines chromatographic separation with a mass spectrum for each component.

Melting point, boiling point and mixed melting point

A pure crystalline substance normally melts over a narrow range close to its reference value. Impurities often depress and broaden melting. A mixed melting point with a known reference can strengthen identification; a depressed/broadened mixture suggests different substances.

Compare boiling points at the same pressure. A similar boiling point alone is weak identification, and some mixtures can boil at a constant temperature.

Elemental / combustion analysis

Use elemental masses or percentages to obtain mole ratios and the empirical formula. From combustion, $n(C) = n(CO_2)$ and $n(H) = 2n(H_2O)$. Oxygen by difference is valid only when the other elements are known and accounted for. Combine the empirical formula with molecular mass to obtain the molecular formula; neither formula alone fixes connectivity.

Polarimetry and UV-visible evidence

A pure enantiomer can rotate plane-polarised light; its partner rotates it equally in the opposite direction under the same conditions. Zero rotation can mean an achiral compound or a racemic mixture. UV-visible absorption and colorimetry can support comparison/quantification of coloured species, but a colour or absorbance alone is not a unique identity.

Titration: identifies amount or acid-base behaviour, rather than a unique molecular structure. Stoichiometry can distinguish candidate formulas when combined with known purity, molar mass and the number of reactive groups.

Use a sequence to distinguish unknowns

Use separate portions. For each pair, state both expected observations.

Candidate pair	A useful test	Expected distinction
Propanal / propanone	Warm Tollens' reagent	Propanal: silver mirror. Propanone: no silver deposit.
Propan-1-ol / propan-2-ol	I_2 / NaOH, warm	Propan-2-ol: yellow CHI_3 precipitate. Propan-1-ol: no yellow precipitate.
Propan-2-ol / 2-methylpropan-2-ol	Acidified dichromate, warm	Secondary alcohol: orange $\rightarrow$ green. Tertiary alcohol: remains orange.
Ethanoic acid / ethanol	$NaHCO_3(aq)$	Acid: CO_2 effervescence, confirmed by limewater. Ethanol: no effervescence.
Phenol / cyclohexene	Bromine water; then supporting $FeCl_3$ on a new sample	Both consume bromine; phenol also gives a white brominated solid and a Fe(III) colour response.
Ethyl ethanoate / butan-2-one	2,4-DNPH	Ketone: yellow/orange precipitate. Ester: no such precipitate.
Zn^{2+} / Al^{3+}	Excess NH_3 after precipitation	Zinc precipitate dissolves; aluminium precipitate remains.
Fe^{2+} / Fe^{3+}	A few drops of NaOH	Green precipitate (browns on standing) versus immediate red-brown precipitate.
Cl^- / Br^- / I^-	HNO_3 then $AgNO_3$; ammonia confirmation	White / cream / yellow; use the different ammonia solubilities.

A complete small example

Unknown X has formula C_3H_6O , gives a DNPH precipitate and a silver mirror, but no iodoform precipitate. It has a proton signal near 9.7 ppm and three carbon environments. **Propanal** fits all of these observations. Naming "a carbonyl" would stop too early; naming "propanone" would contradict Tollens' and the aldehyde proton.

Before submitting: Did you name the reagent and conditions? Distinguish a solid from a solution? State both outcomes? Confirm an evolved gas? Allow for functional groups that share a positive test? Check the entire proposed structure against all the evidence?

Coverage and references

A syllabus-mapped reference, with supporting methods clearly separated from explicit requirements.

Specification area	Handbook coverage
AS 5.5; 8.17-8.19; 8.25-8.27	Alkene test; flames; $\text{CO}_2/\text{O}_2/\text{NO}_2$; carbonate, hydrogencarbonate, sulfate and ammonium; halogens and halides.
AS 10.10; 10.17-10.23; Core Practical 8	Halogenoalkane hydrolysis; PCl_5 ; alcohol oxidation; IR/mass spectra; practical unknowns.
A2 15.8; 15.12-15.23	Carbonyl tests and derivatives, iodoform, acids and derivatives, NMR, accurate mass and chromatography.
A2 17.18-17.24	Vanadium/chromium colours; all eight specified metal ions with NaOH/NH_3 ; ligand exchange.
A2 18.6; 19.2; 19.6; 19.11-19.12; 20.1; 20.5	Phenol, amines, diazotisation/coupling, amino acids, Core Practical 15, combined structural and purity evidence.

Supporting additions: common water/ H_2/Cl_2 tests; $\text{Al}^{3+}/\text{Mg}^{2+}/\text{Ca}^{2+}$ comparisons; nitrate, sulfite, thiosulfate and sulfide tests; Fe(III)-phenol, biuret and ninhydrin. These make the revision reference useful for prior knowledge and unfamiliar contexts, but are not all individually prescribed named tests in the 2018 IAL specification.

Primary curriculum references

Pearson Edexcel IAL Chemistry (2018) specification

Pearson IAL Chemistry data booklet, Issue 1, March 2019

Pearson Chemistry practical guide for teachers

Practical cross-checks: Royal Society of Chemistry

Qualitative tests for organic functional groups · Brady's test

Ethanol/methanol: iodoform · Phenolic impurity in aspirin

Testing salts for anions and cations · Positive ions with NaOH

Transition elements and complex compounds · Flame tests

Completeness has a defined scope: the named identification methods across the 2018 AS/A2 course are covered here. Examinations can introduce unfamiliar reagents or data; use the information given. A single observation rarely identifies every possible compound in an unrestricted unknown sample.