MA99 EDUCATION

Applying Chemical Ideas: Summary

08

NSW CHEMISTRY STAGE 6 SYLLABUS 2017 FOR HSC 2027 AND 2028

1. Identifying cations

ION	REAGENT	OBSERVATION	CONFIRMING SECOND TEST
Barium	Dilute sulfuric acid	White precipitate, insoluble in acid	Apple green flame
Calcium	Carbonate solution	White precipitate	Brick red flame
Lead	Cold chloride solution	White precipitate, dissolves in hot water	Iodide gives bright yellow
Copper	Sodium hydroxide	Pale blue precipitate	Redissolves in excess ammonia to deep blue
Iron(II)	Sodium hydroxide	Green precipitate, darkens in air	No colour with thiocyanate
Iron(III)	Sodium hydroxide	Red brown precipitate	Blood red with thiocyanate

1.1 The net ionic equations

ION	EQUATION
Barium	$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$
Calcium	$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$
Lead with iodide	$Pb^{2+} + 2I^- \rightarrow PbI_2$
Lead with sulfate	$Pb^{2+} + SO_4^{2-} \rightarrow PbSO_4$
Copper	$Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$
Copper in ammonia	$Cu(OH)_2 + 4NH_3 \rightarrow Cu(NH_3)_4^{2+} + 2OH^-$
Iron(II)	$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$
Iron(III)	$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3$
Iron(III) confirmed	$Fe^{3+} + SCN^- \rightarrow FeSCN^{2+}$

1.2 Flame colours

BARIUM	CALCIUM	COPPER	SODIUM	POTASSIUM
Apple green	Brick red	Blue green	Intense yellow	Lilac, through cobalt glass

Sodium masks everything. Clean the wire in concentrated hydrochloric acid between tests and check it gives no colour. Saying so is worth a mark in a practical question.

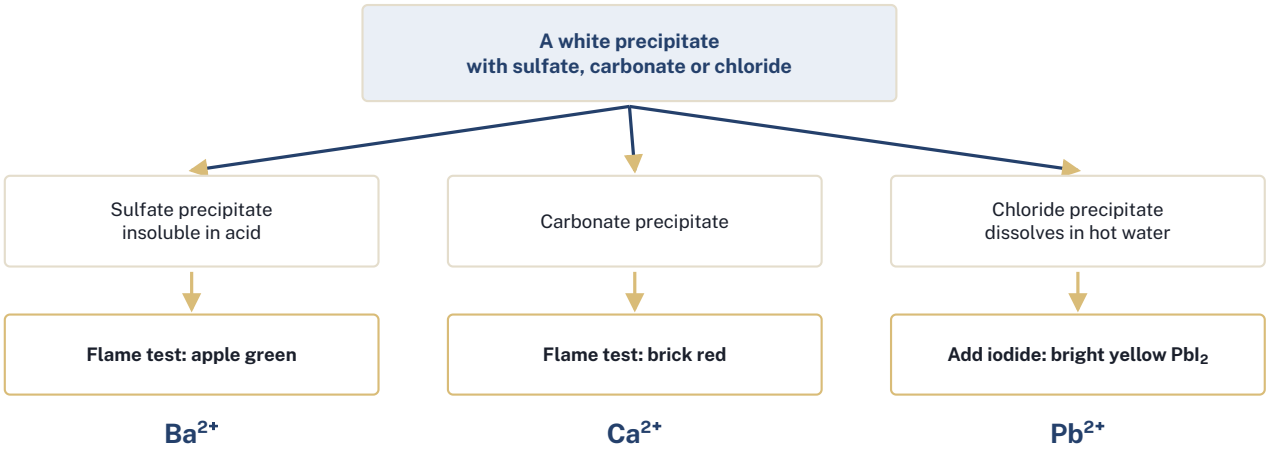


Figure 1 · Three white precipitates, told apart by the confirming test.

2. Identifying anions, and why the order matters

ION	REAGENT	OBSERVATION	EQUATION
Chloride	Silver nitrate, after nitric acid	White, darkens in light	$Ag^+ + Cl^- \rightarrow AgCl$
Bromide	Silver nitrate, after nitric acid	Cream	$Ag^+ + Br^- \rightarrow AgBr$
Sulfate	Barium chloride, after hydrochloric acid	White, insoluble in acid	$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$
Carbonate	Dilute hydrochloric acid	Effervescence, limewater turns milky	$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$
Phosphate	Silver nitrate, neutral	Yellow, soluble in acid	$3Ag^+ + PO_4^{3-} \rightarrow Ag_3PO_4$

Three rules that are each worth a mark

Test for carbonate first, because it precipitates white with both silver and barium and would be mistaken for either.

Acidify before the sulfate and chloride tests, and say which acid and why.

Never acidify with hydrochloric acid before a chloride test.

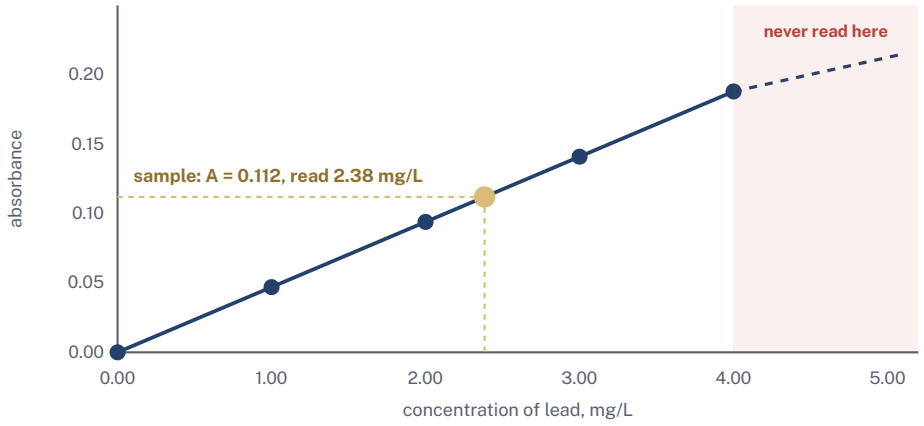
3. The quantitative techniques

TECHNIQUE	WHAT IT MEASURES	HOW THE NUMBER IS OBTAINED	WHAT IT CANNOT DO
Gravimetric analysis	Mass of one ion in a sample	Weigh a precipitate of known formula, then work back through the mole ratio	Cannot work at trace level, and needs a precipitate that is genuinely insoluble
Precipitation titration	Concentration of a halide	Titrate with standard silver nitrate to a chromate end point	The solution must be near neutral, and only works for ions that precipitate with silver
Colourimetry	Concentration of a coloured species	Measure absorbance, read off a calibration line	Only for coloured species, and other coloured ions interfere
Complexometric analysis	Concentration of a metal that forms a complex	Form a coloured complex, then measure it	Needs a ligand selective for that metal

TECHNIQUE	WHAT IT MEASURES	HOW THE NUMBER IS OBTAINED	WHAT IT CANNOT DO
Atomic absorption spectroscopy	A metal at trace levels, parts per million with a flame and lower with a graphite furnace	Absorbance against a calibration curve from standards run in the same session	One element per lamp, and the sample must fall inside the standard range

3.1 The AAS rules that carry marks

- The lamp is made of the element being measured, which is where the selectivity comes from.
- Standards are made from one stock solution and run in the same session on the same instrument as the sample.
- A blank sets the zero. Without it the calibration line has no anchor.
- Never extrapolate past the highest standard. Dilute the sample and run it again, then multiply back by the dilution factor.



gradient 0.0470 per mg/L
intercept zero, as a blanked instrument gives

Beyond the top standard the response bends away. Dilute and run again.

Figure 2 · The calibration line read as an instruction. Interpolate, never extrapolate.

4. Organic tests and chromatography

TESTING FOR	REAGENT	POSITIVE RESULT	THE CONTROL THAT PROVES IT
Carbon to carbon double bond	Bromine water	Orange colour disappears immediately	An alkane leaves it orange unless ultraviolet light is present
Alcohol	Sodium metal	Steady effervescence of hydrogen	A carboxylic acid does this too, so it is not decisive alone
Primary or secondary alcohol	Acidified dichromate, warmed	Orange turns green	A tertiary alcohol leaves it orange
Carboxylic acid	Sodium hydrogencarbonate	Effervescence, limewater turns milky	An alcohol does nothing, which is how the two are separated

4.1 Chromatography

TECHNIQUE	STATIONARY PHASE	MOBILE PHASE	BEST USED FOR
Paper	Water in cellulose	Solvent rising by capillary action	Coloured mixtures, quick screening
Thin layer	Silica on a plate	Solvent rising by capillary action	Checking a reaction is complete
Column	Silica packed in a tube	Solvent flowing under gravity	Separating a useful quantity
High performance liquid	Fine particles in a steel column	Solvent pumped at high pressure	Trace quantitative analysis

Rf, in three lines

Rf = distance moved by the spot divided by distance moved by the solvent front, both measured from the baseline.

It has no units and it cannot exceed one.

It is comparable only between plates run with the same phases and the same conditions, and two different compounds can share a value, so a match is evidence and not proof.

5. Spectroscopy, on one page

5.1 Mass spectrometry

WHAT YOU READ	WHAT IT TELLS YOU
The molecular ion peak	The molar mass of the compound, directly
A fragment 15 below the molecular ion	A methyl group was lost
A fragment 29 below	An ethyl group, or an aldehyde group, was lost
Two peaks two apart in a three to one ratio	Chlorine is present, from chlorine 35 and chlorine 37
Two peaks two apart in about a one to one ratio	Bromine is present

5.2 Infrared

WAVENUMBER, PER CENTIMETRE	SHAPE	BOND	GROUP
3200 to 3600	Broad	O to H	Alcohol
2500 to 3300	Very broad	O to H	Carboxylic acid
3300 to 3500	Two sharper peaks	N to H	Primary amine
1680 to 1750	Sharp and strong	C=O	Aldehyde, ketone, acid or ester
1000 to 1300	Strong	C to O	Alcohol, ester or ether

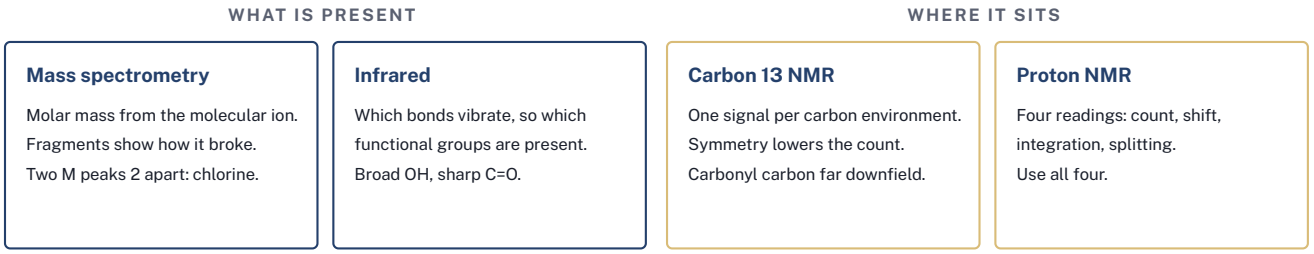
5.3 Proton NMR, the four readings

READING	WHAT IT GIVES YOU
Number of signals	How many different hydrogen environments there are
Chemical shift	What each hydrogen is attached to and what is next to it
Integration	How many hydrogens are in each environment
Splitting	How many hydrogens are on the neighbouring carbon: n neighbours give n plus 1 lines

5.4 Carbon 13 NMR

- One signal for each different carbon environment. No splitting to read.
- Carbonyl carbon: about 160 to 220 ppm, far from everything else (acids and esters about 160 to 185, aldehydes and ketones about 190 to 220). Carbon bonded to oxygen: about 50 to 90 ppm. Alkane carbon: below about 50 ppm.
- Fewer signals than carbons means the molecule is symmetrical, and that drop is itself the evidence.

5.5 The order for a combined spectra question



Work in this order: mass spectrum, combustion analysis, infrared, carbon NMR, proton NMR, then one structure with each piece of evidence cited.

Figure 3 · What each instrument is for. Cite the evidence beside every conclusion: same chemistry, one more clause, several more marks.

ORDER	EVIDENCE	WHAT IT SETTLES
1	Molecular ion from the mass spectrum	The molar mass
2	Combustion analysis or percentage composition	The empirical, then the molecular formula
3	Infrared	Which groups are present and which are absent
4	Carbon 13 NMR	The number of carbon environments, so the symmetry
5	Proton NMR	Where the hydrogens sit
6	All of it	One structure, with the evidence cited beside each step

6. Synthesis and monitoring

6.1 Designing a synthesis

- Work backwards from the target to the starting material.
- Give the reagent and the conditions for each step, not just the reagent.
- Say how each intermediate is separated before the next step runs.
- Multiply the step yields to get the overall yield. Two steps at 80 per cent give 64 per cent, which is the argument for a short route.
- Say where the atom economy is lost and whether the by product has a use.

6.2 Monitoring, and why sampling decides the answer

REQUIREMENT	WHY	WHAT GOES WRONG WITHOUT IT
Fixed sampling point and time	So a change in the result means a change in the river	A result that reflects the weather rather than the discharge
Composite rather than grab sampling	So the result describes the discharge, not one instant	A single unrepresentative moment reported as typical
Acidify metals, chill everything	Metals adsorb onto glass and organics degrade	A result that is systematically low
A field blank carried through every step	To separate contamination from the sample	Lead from the bottle reported as lead from the river
Comparison with a stated guideline	A number alone is not a conclusion	A correct measurement with no finding attached to it

6.3 Heavy metals

- They do not break down. They can only be moved, diluted or locked up.
- Bioaccumulation: the concentration inside an organism rises over its lifetime, so water at a safe concentration can still produce an unsafe body burden.
- Biomagnification: for a metal passed on efficiently (mercury is the usual example), each step up the food chain concentrates it again.
- Sediment is both the historical record and a reservoir. Licence condition KR 14 keeps the river pH above 6.5 precisely so the metals stay locked in it.

6.4 The ten things most often lost

WHAT GOES WRONG	THE FIX, IN ONE LINE
An observation with no reagent named	Reagent first, observation second, in one sentence
One precipitate treated as an identification	Always give a confirming second test
No net ionic equation	Write it whether or not it was asked for
Testing for sulfate without acidifying	Carbonate would give the same white solid
Acidifying with hydrochloric acid before a chloride test	You would be adding the ion you are testing for
An answer in the wrong unit	Read the question again and convert. Milligrams per litre is not grams per litre
Extrapolating past the top standard	Dilute, rerun, then multiply back
Reading only the chemical shift in an NMR	Use all four readings or you have guessed
A conclusion with no evidence cited	Name the band or the peak beside every claim
A number with no comparison	Compare it with the guideline, then say what it means

> If a row surprises you, that is tonight's reading. If none does, close this and sit a question under time.

About this resource

MA99 EDUCATION

Scope

NSW Chemistry, Year 12. Written to the NSW Chemistry Stage 6 Syllabus (2017), Module 8, for students sitting the HSC in 2027 and 2028. A new Chemistry syllabus is first examined in HSC 2029.

Permitted use

Print it, annotate it and keep it on any device you own, for your own study.

Not permitted

Sharing, posting, selling or redistributing it, in whole or in part. Each copy is licensed to one student.

Copyright MA99 Education.
ma99education.com.au