MA99 EDUCATION

Properties and Structure of Matter: Topic Notes

01

NSW CHEMISTRY STAGE 6 SYLLABUS 2017 FOR HSC 2028

1. Classifying matter

Matter is anything that has mass and takes up space. Chemists classify it first as a pure substance or a mixture.

- **Element:** a pure substance made of only one type of atom, for example copper or oxygen.
- **Compound:** a pure substance made of two or more elements chemically bonded in a fixed ratio, for example water.
- **Mixture:** two or more substances physically combined and not chemically bonded, so they keep their own properties.

A **homogeneous** mixture has a uniform composition throughout, for example salt water. A **heterogeneous** mixture does not, for example sand and water.

Physical and chemical properties

Physical property: observed without changing the substance, for example melting point, density, colour, conductivity and solubility.

Chemical property: describes how a substance reacts, for example flammability or reactivity with acid.

2. Separating mixtures

Mixtures are separated by exploiting differences in the physical properties of their components. The method chosen depends on the property that differs.

TECHNIQUE	PHYSICAL PROPERTY USED	EXAMPLE
Filtration	Particle size (solid from liquid)	Sand from water
Decantation	Density, settling	Pouring off water from sediment
Evaporation	Volatility (boiling point)	Salt from salt water
Distillation	Difference in boiling point	Pure water from salt water
Separating funnel	Immiscibility and density	Oil from water
Magnetic separation	Magnetism	Iron filings from sulfur
Chromatography	Solubility and adsorption	Dyes in an ink

Percentage composition by mass gives the fraction of a mixture that is one component. For a component, percentage by mass = (mass of component / total mass) × 100.

3. Inside the atom

Every atom is built from three subatomic particles. Protons and neutrons sit in a tiny central nucleus, and electrons occupy shells around it.

PARTICLE	CHARGE	RELATIVE MASS	LOCATION
Proton	+1	1	Nucleus

PARTICLE	CHARGE	RELATIVE MASS	LOCATION
Neutron	0	1	Nucleus
Electron	-1	about 1/1836	Shells around the nucleus

Atomic number (Z): the number of protons, which defines the element. **Mass number (A):** the number of protons plus neutrons. Number of neutrons = A minus Z.

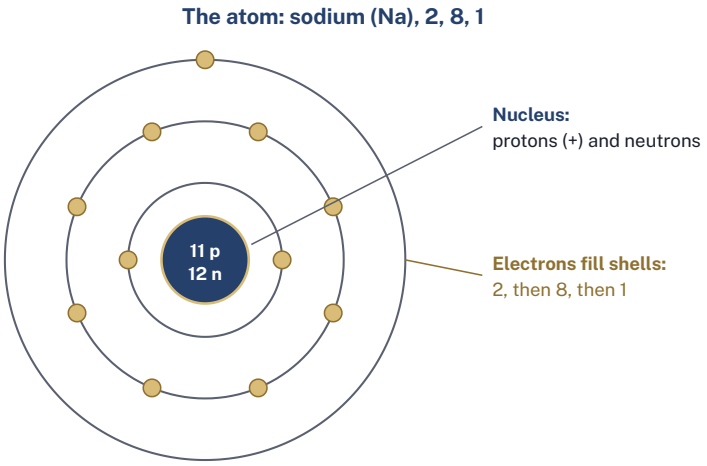


Figure 1 · A sodium atom has 11 protons and 12 neutrons in the nucleus, with electrons arranged 2, 8, 1.

Isotopes are atoms of the same element (same number of protons) with different numbers of neutrons, so they have the same atomic number but different mass numbers. For example, chlorine-35 and chlorine-37 are isotopes of chlorine.

4. Relative atomic mass

Because an element is usually a mixture of isotopes, we use a weighted average called the relative atomic mass. It is the average mass of an atom on a scale where a carbon-12 atom is exactly 12.

Worked example: the relative atomic mass of chlorine

Chlorine is 75.0 per cent chlorine-35 and 25.0 per cent chlorine-37. The relative atomic mass is the weighted average:

$$A_r = (0.750 \times 35) + (0.250 \times 37)$$

$$A_r = 26.25 + 9.25 = 35.5$$

This matches the value on the periodic table, 35.45.

5. Electron configuration

Electrons occupy shells (energy levels) around the nucleus. The first shell holds up to 2 electrons, the second up to 8, and the third up to 8 for the first 20 elements. Sodium is written 2, 8, 1.

The spdf notation describes the sub-shells electrons occupy. Sodium is $1s^2\ 2s^2\ 2p^6\ 3s^1$.

Evidence for energy levels. When atoms are heated, electrons jump to higher levels and then fall back, releasing light of set colours. This gives each element a characteristic flame colour and emission spectrum, which is strong evidence for discrete energy levels.

METAL ION	FLAME COLOUR
Lithium	Crimson red
Sodium	Yellow
Potassium	Lilac
Calcium	Brick red
Barium	Green
Copper	Blue green

Flame colours are electrons falling back down and releasing energy as light.

6. Periodicity

The periodic table is arranged by increasing atomic number, with elements in vertical groups sharing similar properties and horizontal periods showing gradual change. This order reveals clear trends.

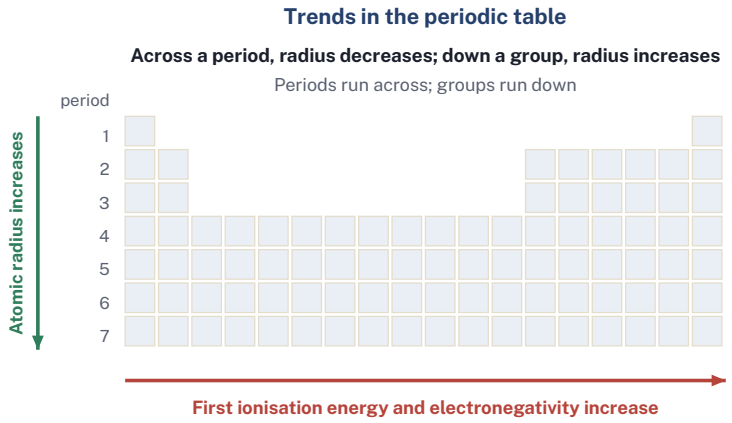


Figure 2 · Atomic radius increases down a group and decreases across a period; ionisation energy and electronegativity increase across a period.

TREND	ACROSS A PERIOD (LEFT TO RIGHT)	DOWN A GROUP
Atomic radius	Decreases (stronger nuclear pull)	Increases (more shells)
First ionisation energy	Increases	Decreases
Electronegativity	Increases	Decreases
Metallic character	Decreases	Increases

Key idea: explaining the trends

Across a period the nuclear charge rises while electrons enter the same shell, so the atom is pulled in tighter, making it smaller and harder to remove an electron.

Down a group each element has an extra full shell, so the outer electrons are further from the nucleus and more shielded, making the atom larger and easier to ionise.

7. Chemical bonding

Atoms bond to reach a stable electron arrangement, usually a full outer shell. There are three main types of bonding.

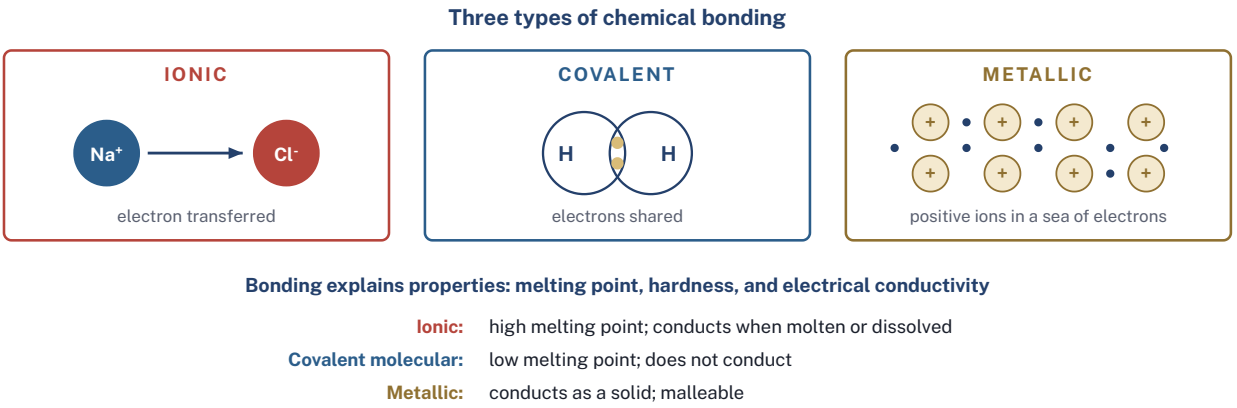


Figure 3 · Ionic bonding transfers electrons, covalent bonding shares them, and metallic bonding pools them in a sea of electrons.

7.1 Ionic bonding

A metal transfers one or more electrons to a non-metal. The metal becomes a positive cation and the non-metal a negative anion, and the opposite charges attract. Sodium chloride forms as Na gives an electron to Cl to make Na^+ and Cl^-, written NaCl.

Ionic compounds form giant lattices. They have high melting points and conduct electricity only when molten or dissolved, because the ions are then free to move.

7.2 Covalent bonding

Two non-metals share pairs of electrons. A water molecule, H_2O, shares electrons between oxygen and each hydrogen. Covalent molecular substances have low melting points and do not conduct electricity.

7.3 Metallic bonding

Metal atoms release their outer electrons into a shared sea of delocalised electrons around positive ions. This explains why metals conduct electricity, are malleable, and have generally high melting points.

7.4 Structures and intermolecular forces

Covalent network solids such as diamond and silicon dioxide, SiO_2, have covalent bonds throughout the lattice, so they are very hard with very high melting points.

Intermolecular forces act between molecules and are much weaker than the covalent bonds within them. From weakest to strongest they are dispersion forces, dipole-dipole forces and hydrogen bonding. They explain why molecular substances melt and boil at low temperatures. Section 11 treats them in detail.

Allotropes are different structural forms of the same element, for example diamond and graphite are both carbon but have very different properties because their atoms are arranged differently.

8. Drawing covalent molecules: Lewis structures

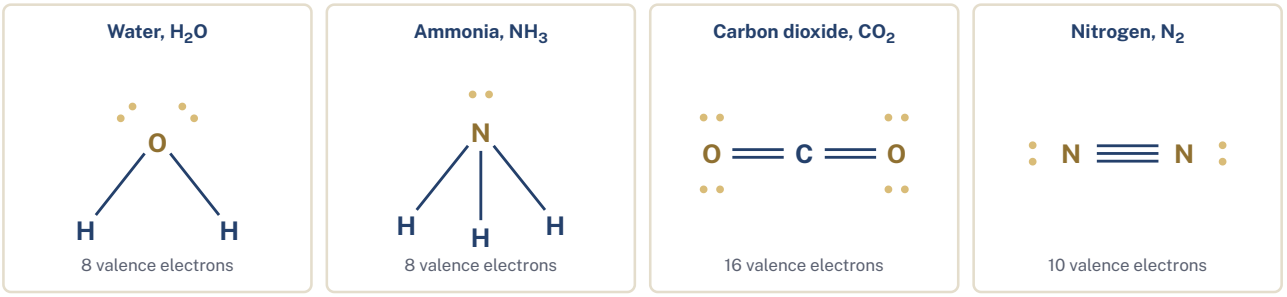
A **Lewis structure** shows every valence electron in a molecule: each shared pair is a line, and each lone pair (a pair on one atom, not shared) is a pair of dots. It is the first step to the shape and the polarity of a molecule.

Valence electrons. For a main group element the number of valence electrons equals the group number (1 for hydrogen, 4 for carbon, 5 for nitrogen, 6 for oxygen, 7 for fluorine and chlorine). The aim is an octet (8 electrons) around each atom, or a duet (2) around hydrogen.

Key idea: the six steps

1. Add the valence electrons of all atoms. For an ion, add one electron for each negative charge and take one away for each positive charge.
2. Choose the central atom: the least electronegative atom, and never hydrogen.
3. Join each outer atom to the centre with a single bond (2 electrons each).
4. Put lone pairs on the outer atoms until each has an octet (hydrogen has its duet already).
5. Put any electrons left over on the central atom as lone pairs.
6. If the central atom has fewer than 8 electrons, move a lone pair from an outer atom into the bond to make a double or triple bond. Recount.

Lewis structures: bonds are lines, lone pairs are dot pairs



Each atom in a molecule is counted with 8 electrons around it (2 for hydrogen): bonding pairs plus lone pairs.

Figure 4 · Lewis structures of four small molecules. The electron count at the foot of each box is the total from step 1.

Worked example: carbon dioxide

Step 1. Carbon has 4 valence electrons and each oxygen has 6, so the total is 4 + 6 + 6 = 16.

Steps 2 and 3. Carbon is central: O-C-O uses 2 × 2 = 4 electrons.

Step 4. Each oxygen needs 6 more electrons for an octet, which uses 6 + 6 = 12. Total used: 4 + 12 = 16, so nothing is left for carbon.

Step 6. Carbon has only 4 electrons around it (two single bonds). Move one lone pair from each oxygen into a bond: O=C=O. Carbon now has 8 electrons and each oxygen still has 8 (two bonds and two lone pairs).

Check: 4 shared pairs + 4 lone pairs = 8 pairs = 16 electrons.

Worked example: ammonia and nitrogen

Ammonia. Valence electrons: 5 + 3 × 1 = 8. Nitrogen is central with three single bonds to hydrogen, which uses 6 electrons. The remaining 2 electrons are one lone pair on nitrogen. Nitrogen has 3 bonding pairs and 1 lone pair, so 8 electrons around it.

Nitrogen. Valence electrons: 5 + 5 = 10. A single bond N-N leaves 8 electrons, which give each nitrogen only 6 around it. Moving lone pairs into the bond gives a triple bond (three shared pairs) with one lone pair on each nitrogen. Each nitrogen has 6 + 2 = 8 electrons.

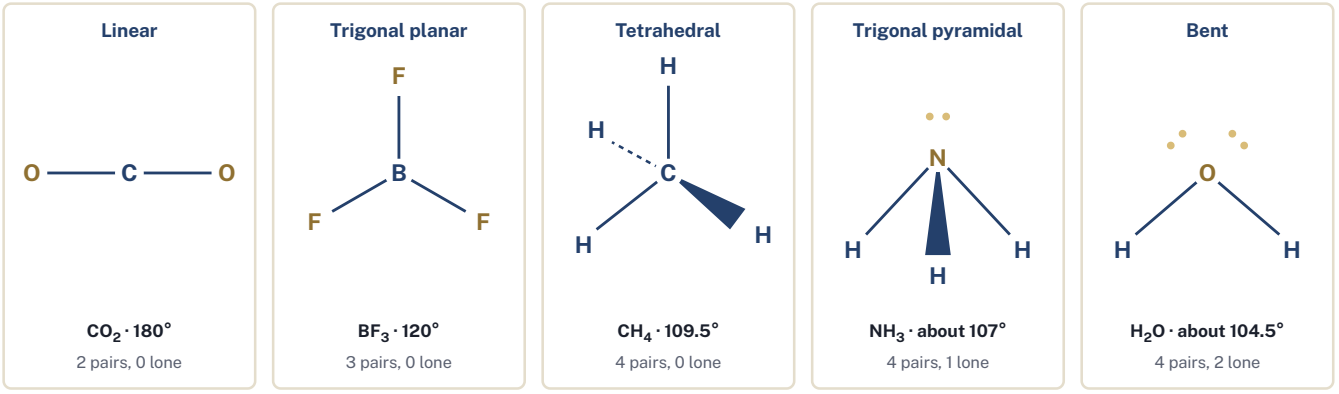
Bond order. A bond with more shared pairs is shorter and stronger. A triple bond is shorter and stronger than a double bond, which is shorter and stronger than a single bond between the same two atoms. This is why nitrogen gas, with its triple bond, is very unreactive.

9. Molecular shape: VSEPR theory

VSEPR stands for valence shell electron pair repulsion. Electron pairs around a central atom repel one another, so they spread as far apart as possible. The shape of the molecule is the arrangement of the **atoms**, not of the lone pairs, although the lone pairs push the bonds into position.

To use it, count the **regions of electron density** around the central atom. A single, double or triple bond to one atom counts as one region, and each lone pair counts as one region.

Molecular shape from the number of electron pairs around the central atom



Gold dot pairs are lone pairs. A double or triple bond counts as one pair-region when you count regions.

Figure 5 · Five shapes you must be able to name, with the bond angle and the number of bonding regions and lone pairs.

Worked example: predict the shape of water and carbon dioxide

Water. The Lewis structure of H_2O has 2 bonding pairs and 2 lone pairs on oxygen, so 4 regions. Four regions give a tetrahedral arrangement of pairs, but only two of the four positions hold atoms, so the molecule is **bent** with an angle a little under 109.5° (lone pairs repel more strongly than bonding pairs).

Carbon dioxide. Each C=O double bond counts as one region, so carbon has 2 regions and no lone pairs: **linear**, 180°.

Both molecules have two polar bonds. Their shapes differ, which is why water and carbon dioxide behave so differently (Section 10).

Why the angles shrink. A lone pair is held by one nucleus only, so it takes more room than a bonding pair and squeezes the bonds together: 109.5° in methane, about 107° in ammonia (one lone pair) and about 104.5° in water (two). The two smaller angles are measured values rounded here.

10. Polarity of bonds and molecules

Electronegativity is the attraction an atom has for the shared electrons in a bond. When two different atoms share electrons, the more electronegative atom pulls the pair closer, so it carries a partial negative charge (δ^-) and the other a partial positive charge (δ^+). That is a **polar bond**.

ATOM	H	C	N	O	F	Cl	Na
Electronegativity (Pauling)	2.20	2.55	3.04	3.44	3.98	3.16	0.93

Pauling electronegativities from the Los Alamos National Laboratory Periodic Table of Elements, accessed 7 October 2026.

The difference in electronegativity, ΔEN, is a guide to bond type. As a rough rule: below about 0.4 the bond is non-polar covalent, from about 0.4 to about 1.7 it is polar covalent, and above about 1.7 it is mainly ionic. The limits are a convenient guide, not sharp boundaries.

Worked example: bond polarity.

BOND	ΔEN	TYPE	PARTIAL CHARGES
C-H	2.55 − 2.20 = 0.35	non-polar (nearly)	none
N-H	3.04 − 2.20 = 0.84	polar covalent	δ^- on N
H-Cl	3.16 − 2.20 = 0.96	polar covalent	δ^- on Cl
O-H	3.44 − 2.20 = 1.24	polar covalent	δ^- on O
Na-Cl	3.16 − 0.93 = 2.23	ionic	Na^+ and Cl^-

A polar bond does not guarantee a polar molecule. A molecule is polar only if its bond dipoles do not cancel. The shape decides.

Carbon dioxide (linear) and methane (tetrahedral) are non-polar because their dipoles cancel. Ammonia (trigonal pyramidal), water (bent) and hydrogen chloride (two atoms, one dipole) are polar because theirs do not.

At the Kerrindal Works (invented plant) the assay laboratory dissolves ore samples in water because water is polar: its δ^- oxygen attracts cations and its δ^+ hydrogens attract anions. It cleans grease from glassware with a non-polar solvent, because like dissolves like.

11. Intermolecular forces in detail

Covalent bonds hold atoms together **within** a molecule. Intermolecular forces act **between** molecules. They are far weaker, so when a molecular substance melts or boils it is the intermolecular forces that are overcome, not the covalent bonds.

FORCE	ACTS BETWEEN	STRENGTH	INCREASES WITH
Dispersion (London)	all molecules, polar or not	weakest	more electrons, larger molecule
Dipole-dipole	polar molecules	stronger	greater polarity
Hydrogen bonding	molecules with H bonded to N, O or F, and a lone pair on a nearby N, O or F	strongest	(needs the O-H, N-H or F-H bond)

Dispersion forces. The electrons in a molecule are always moving, so for an instant one side of the molecule has slightly more negative charge. That temporary dipole causes a temporary dipole in a neighbour, and the two attract. Every molecule has them. A larger molecule has more electrons that can be shifted, so its dispersion forces are stronger.

Dipole-dipole forces. A polar molecule has a permanent dipole. The δ^+ end of one molecule attracts the δ^- end of the next, in addition to dispersion forces.

Hydrogen bonding. A hydrogen atom bonded to N, O or F carries a large δ^+ charge and has no inner electrons to shield it, so it is strongly attracted to a lone pair on an N, O or F atom in a neighbouring molecule. It is not a covalent bond. Water, ammonia, hydrogen fluoride and alcohols form hydrogen bonds.

Worked example: explain the boiling points of ethanol and dimethyl ether

Ethanol, C_2H_5OH, boils at 78.4 °C (NIST Chemistry WebBook, 351.5 K, accessed 7 October 2026). Dimethyl ether, CH_3OCH_3, boils at about -25 °C. Both have the molecular formula C_2H_6O and the molar mass 46.07 g/mol. Explain the difference.

Answer. The two molecules have the same number of electrons, so their dispersion forces are about equal. Ethanol has an O-H bond, so its molecules form hydrogen bonds with each other. Dimethyl ether has no hydrogen bonded to oxygen, so it has only dipole-dipole and dispersion forces. Hydrogen bonds are stronger than dipole-dipole forces, so more energy is needed to separate ethanol molecules, and ethanol boils about 100 °C higher.

Worked example: methane, hydrogen sulfide and water

Methane boils at −161.5 °C, hydrogen sulfide at −60.3 °C and water at 100.0 °C (NIST Chemistry WebBook and PubChem, Hazardous Substances Data Bank records, accessed 7 October 2026).

Methane is non-polar and has only dispersion forces. Hydrogen sulfide has 18 electrons against 10 in methane and is slightly polar, so its dispersion and dipole-dipole forces are stronger, and it boils higher. Water has fewer electrons than hydrogen sulfide, yet it boils 160 °C higher, because its O-H bonds form hydrogen bonds. That is the one comparison in this set where a smaller molecule boils higher, and the reason is the type of force.

Key idea: the four-step explanation

When asked why one substance boils or melts higher than another, write four short statements: **(1)** name the type of substance (molecular), **(2)** name the strongest force in each, **(3)** say which force is stronger and why (more electrons, a dipole, an O-H, N-H or F-H bond), **(4)** link to energy: more energy is needed to overcome the stronger force, so the boiling point is higher. Never say that covalent bonds break when a molecular substance boils.

12. Exam focus and checks

Exam focus: Module 1

Link structure to properties: always explain melting point, hardness and conductivity in terms of the bonding and structure present.

Show the working for relative atomic mass as a weighted average of the isotopes.

Use the trends to predict: state whether a property increases or decreases and give the reason (nuclear charge, shells, shielding).

For a molecule, work in order: Lewis structure, count regions, name the shape, decide polarity from the shape, name the strongest intermolecular force.

Check your understanding

1. Classify air, salt water and iron as element, compound or mixture.
2. An atom has 17 protons and 18 neutrons. State its atomic number and mass number.
3. Bromine is 50.7 per cent Br-79 and 49.3 per cent Br-81. Estimate its relative atomic mass.
4. Explain why sodium chloride conducts electricity when molten but not when solid.
5. Explain why atomic radius decreases across a period.
6. Draw the Lewis structure of hydrogen chloride, HCl, and of methane, CH_4, and state how many lone pairs each central atom has.
7. Name the shape of ammonia and explain why its bond angle is smaller than that of methane.
8. Carbon tetrachloride, CCl_4, has four polar C-Cl bonds but is a non-polar molecule. Explain.
9. Explain, using the strongest intermolecular force in each, why hydrogen fluoride (boiling point about 20 °C) boils higher than hydrogen chloride (−85 °C).
10. State the number of valence electrons in the sulfate ion, SO_4^{2-}.

Answers to the checks

1. Air is a mixture, salt water is a mixture (a solution), iron is an element. **2.** Atomic number 17, mass number 35. **3.** (0.507 × 79) + (0.493 × 81) = 79.99. **4.** Molten, the Na^+ and Cl^- ions are free to move and carry charge; in the solid they are fixed in the lattice. **5.** Nuclear charge increases while the shells stay the same, so the outer electrons are pulled in more strongly. **6.** HCl: H-Cl with 3 lone pairs on Cl (8 valence electrons). CH_4: four C-H single bonds and no lone pairs on C (8 electrons). **7.** Trigonal pyramidal; the lone pair on nitrogen repels the bonding pairs more strongly than they repel each other, so the angle is about 107° rather than 109.5°. **8.** The four dipoles point from carbon to chlorine and are arranged symmetrically in a tetrahedron, so they cancel. **9.** HF forms hydrogen bonds (H bonded to F); HCl has dipole-dipole and dispersion forces only, so less energy separates its molecules. **10.** 6 (sulfur) + 4 × 6 (oxygen) + 2 (for the 2-charge) = 32. (Boiling points: NIST Chemistry WebBook for HF, 292.7 K; PubChem, Hazardous Substances Data Bank record for HCl; accessed 7 October 2026.)

About this resource

MA99 EDUCATION

Scope

NSW Chemistry, Year 11. Written to the NSW Chemistry Stage 6 Syllabus (2017), Module 1, for students sitting the HSC in 2028. A new Chemistry syllabus is first examined in HSC 2029. Every number in it was recomputed from its inputs before printing. Real data are named with their source; contexts at the Kerrindal Works are invented.

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MA99 EDUCATION

Properties and Structure of Matter: Practice Questions 01

NSW CHEMISTRY STAGE 6 SYLLABUS 2017 FOR HSC 2028

1. Instructions

Read this page once. It changes what the rest of the booklet is worth.

Do the questions before you read the solutions. A solution read cold gives a feeling of understanding without evidence of it. A solution read after an attempt shows where the attempt differed.

Work under time. Allow about one and a half minutes for each multiple choice question and about two minutes a mark in Section II. Most students who lose marks in this module know the chemistry. They ran out of room to show it.

Write the formula before the numbers. In every calculation in this booklet, a stated formula carries a mark even when the arithmetic that follows it slips. That is not folklore: it is how method marks are allocated in the marking guidelines, and it is the cheapest habit in the course.

The booklet runs in this order:

- Section I, twelve multiple choice questions, banded by difficulty.
- Section II, nine short answer and calculation questions worth 32 marks.
- Section III, one extended response worth 8 marks.
- Extra practice, three further items numbered 23 to 25, outside the section totals.
- Worked solutions for every question, then a marking guide for the extended response.
- A timed drill and a bonding audit to run weekly between now and the examination.

The solutions start on a fresh page. Fold the booklet back at that page and do not open it until every question has an attempt.

1.1 Where you actually are in Module 1

Ten statements. Tick only the ones you could do right now, on paper, without a prompt. Tick what is true today, not what was true after the last test or will be true after one more read. The routing below is accurate only if the ticks are.

- ☐ I can state the difference between a pure substance and a homogeneous mixture using evidence, not appearance
- ☐ I can choose a separation technique by naming the property difference it exploits
- ☐ I can write the electron configuration of a first row transition metal
- ☐ I can calculate relative atomic mass from isotopic abundances without being shown the formula
- ☐ I can work an abundance backwards from a known relative atomic mass
- ☐ I can explain a periodic trend using nuclear charge and shielding in the same sentence
- ☐ I can predict whether a compound is ionic, covalent or metallic from its elements
- ☐ I can explain why an ionic solid does not conduct but the molten liquid does
- ☐ I can rank three substances by boiling point and justify the order by intermolecular force
- ☐ I can explain why two allotropes of the same element have different properties

1.2 Interpreting your score

Count the ticks and read the matching row.

TICKS	WHAT IT MEANS	GO HERE FIRST
0 to 3	The content is not yet in place. Practice questions will feel like a test rather than a tool.	Read the Module 1 Topic Notes first, then come back and do Section I only.
4 to 6	You know the facts and the linking is unreliable. This is the commonest place to be in Term 1.	Section I in full, then Section II questions 13 to 17. Leave Section III for a second pass.
7 to 8	Solid. Your losses are in explanation questions, not recall.	Skip to Section II question 15, then do Section III under time before reading a single solution.
9 or 10	You are ready for the hard end. Do not reward yourself with the easy questions.	Section I challenge band only, all of Section II, then Section III in 20 minutes.

Date this. Run the same statements again at the end of term and compare the result with this one to measure progress.

First run. Date: _____ **Score:** _____

End of term. Date: _____ **Score:** _____

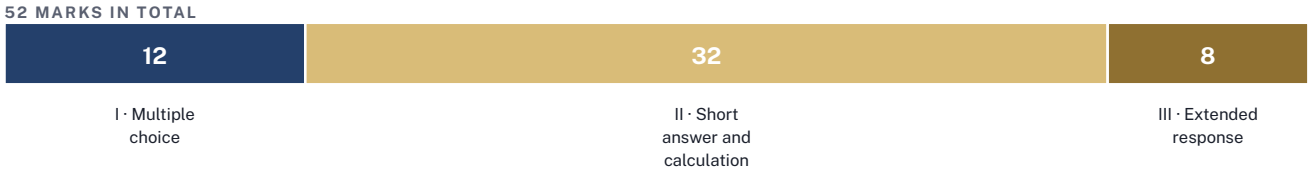


Figure 1 · How the 52 marks are split across the sections. Your time should follow the same split.

2. Section I · Multiple choice

Twelve questions. Allow eighteen minutes. One mark each. Answer every question, including the ones you are unsure of. A blank scores zero and a considered guess between two options scores half the time. In Section I there is no mark for working and no penalty for a wrong answer, so the only bad choice is the empty one.

HOW THE DIFFICULTY BANDS WORK

Every question in Section I carries a band. The bands are not a prediction of your mark. They tell you what a question is testing, so that when you get one wrong you know whether the problem is recall, application or reasoning under an unfamiliar context.

FOUNDATION Recall and one step application. CONSOLIDATION Two steps, or one step in an unfamiliar context. CHALLENGE Reasoning from a principle, a tempting distractor, or an unfamiliar setting. If you miss a Foundation question, go back to the Topic Notes first.

2.1 Section I answer grid

Fill the last column when you mark it. Recall, arithmetic, misread the stem, or chose a distractor that was true but did not answer the question. Four words is enough. The pattern across twelve rows is the thing worth having.

QUESTION	YOUR ANSWER	CORRECT	IF WRONG, WHAT WENT WRONG
1			
2			
3			
4			
5			
6			

QUESTION	YOUR ANSWER	CORRECT	IF WRONG, WHAT WENT WRONG
7			
8			
9			
10			
11			
12			

FOUNDATION

Questions 1 to 4. Recall and one step application.

Question 1

1 MARK

Which of these is a pure substance?

A Filtered river water from the Kerrindal intake
B Copper(I) sulfide, Cu_2S, separated from the ore
C The crushed ore delivered to the assay laboratory
D Air sampled above the calciner

Question 2

1 MARK

Crushed Kerrindal ore, which contains insoluble calcite, is stirred into water to make a slurry. Which technique separates the solid ore particles from the water?

A Distillation
B Filtration
C Chromatography
D Electrolysis

Question 3

1 MARK

An atom of an isotope is described as ^{65}Cu. Which statement is correct?

A It has 65 protons
B It has 65 neutrons
C It has 29 protons and 36 neutrons
D It has 29 protons and 65 neutrons

Question 4

1 MARK

Which substance conducts electricity as a solid?

A Sodium chloride
B Copper
C Solid carbon dioxide
D Sulfur

CONSOLIDATION

Questions 5 to 9. Two steps, or one step in an unfamiliar context.

Question 5

1 MARK

Which electron configuration is correct for a neutral calcium atom?

A $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2$
B $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$
C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4\ 4s^4$
D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

Question 6

1 MARK

Across Period 3, from sodium to chlorine, the atomic radius decreases. The best explanation is that

A the number of occupied electron shells decreases

B nuclear charge increases while the electrons are added to the same shell

C shielding increases faster than nuclear charge

D the atoms become more metallic and pack more closely

Question 7

1 MARK

Magnesium oxide melts at 2852 degrees Celsius while sodium chloride melts at 801 degrees Celsius. Both are ionic. The best explanation for the difference is that

A magnesium oxide has covalent character and sodium chloride does not

B the ions in magnesium oxide carry charges of 2 while those in sodium chloride carry charges of 1

C magnesium oxide has a larger lattice

D sodium chloride dissolves in water and magnesium oxide does not

Question 8

1 MARK

Three substances are compared: butane, propanone and propanol. Propanol has the highest boiling point of the three. The reason is that propanol molecules

A are the largest of the three

B form hydrogen bonds with one another because the oxygen carries a bonded hydrogen

C contain stronger covalent bonds

D are ionic in solution

Question 9

1 MARK

Copper exists as two stable isotopes, ^{63}Cu at 69.15 per cent and ^{65}Cu at 30.85 per cent, with isotopic masses 62.93 and 64.93. The relative atomic mass of copper is closest to

A 63.55

B 63.93

C 64.00

D 64.54

CHALLENGE

Questions 10 to 12. Reasoning from a principle, or a distractor that rewards care.

Question 10

1 MARK

An element from the Kerrindal assay has two isotopes of isotopic mass 84.91 and 86.91. The lighter isotope has an abundance of 72.17 per cent. The relative atomic mass of this element is closest to

A 85.47

B 85.91

C 86.35

D 86.91

Question 11

1 MARK

Diamond and graphite are both allotropes of carbon. Graphite conducts electricity and diamond does not. The reason is that in graphite

A the carbon atoms are held by metallic bonding

B each carbon forms three covalent bonds, leaving one electron per atom delocalised between the layers

C the layers slide, and sliding layers carry charge

D the covalent bonds are weaker than those in diamond

Question 12

1 MARK

A solid X has a melting point of 1495 degrees Celsius, does not conduct as a solid, conducts when molten, and is brittle. A solid Y melts at 113 degrees Celsius, does not conduct in any state, and is soft. Which row correctly identifies the bonding in X and in Y?

A X metallic, Y covalent molecular

B X ionic, Y covalent molecular

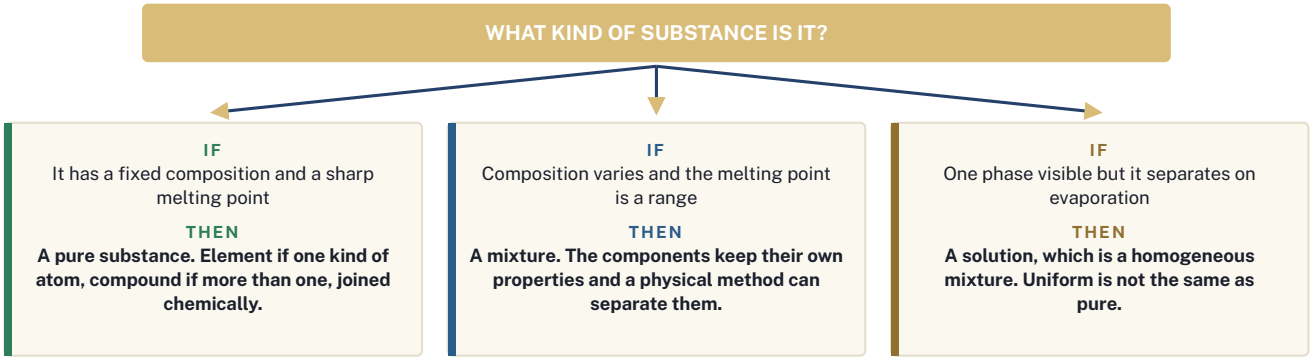
C X covalent network, Y ionic

D X ionic, Y metallic

> A clear liquid tells you nothing. The melting behaviour tells you everything.

PURE OR MIXED, DECIDED BY EVIDENCE NOT BY APPEARANCE

A clear colourless liquid can be any of the three. The melting behaviour tells you which.



Homogeneous is about uniformity. Pure is about composition. Students merge them and lose the mark.

Figure 2 · Pure against mixed, decided by the evidence rather than by how it looks.

3. Section II · Short answer and calculation

Nine questions, 32 marks. Allow about seventy minutes. Show your working. In a calculation question the formula you quote before substituting is worth a mark on its own, and in an explanation question the sentence that links the structure to the property is where the marks sit. Write in the space provided; if you run out, that usually means you are describing rather than explaining.

Question 13

3 MARKS

A sample of the Kerrindal ore is described in the plant log as a heterogeneous mixture of chalcocite, galena and calcite. Explain what the word heterogeneous tells a chemist about this sample, and state one observation that would support the description.

Question 14

5 MARKS

The assay laboratory receives a 250.0 g ore sample that is 31.2 per cent calcite by mass. The calcite is separated from a water slurry by filtration. The retained solid is dried and weighs 46.8 g, of which 2.4 g is filter paper fibre carried through in the weighing.

(a) Calculate the mass of calcite in the original sample. **1 MARK**

(b) Calculate the percentage of the calcite that was recovered. **2 MARKS**

(c) State one property difference that makes filtration the correct choice here, and name one technique that would not work. **2 MARKS**

Question 15

4 MARKS

Write the full electron configuration of a neutral iron atom, and of the Fe^{2+} ion. Explain which electrons are removed first and why that order surprises students.

Question 16

3 MARKS

Boron has two stable isotopes of isotopic mass 10.01 and 11.01, and a relative atomic mass of 10.81. Calculate the percentage abundance of the heavier isotope. Show your working.

THE FORCES, IN ORDER, AND THE ONE THAT IS NOT ON THE LIST

Boiling a molecular substance separates molecules. It does not break bonds within them.

Dispersion only	**Weakest**	All molecules have it. Grows with the number of electrons.
Dipole to dipole	**Stronger**	Needs a permanent polar molecule with an unsymmetrical shape.
Hydrogen bonding	**Strongest of the three**	Only where H is bonded to N, O or F.
Covalent bond	**Not an intermolecular force at all**	Inside the molecule. Boiling does not break it.

Saying the covalent bonds break on boiling costs the mark every single time.

Figure 3 · The intermolecular forces in order, with the one that is not an intermolecular force at all.

Question 17

3 MARKS

Calculate the percentage by mass of copper in chalcocite, Cu_2S. Then state, with a reason, whether an ore assaying 18.0 per cent copper by mass could be pure chalcocite.

Question 18

3 MARKS

Sodium reacts with chlorine to form sodium chloride. Write the balanced equation, then describe what happens to the electrons and name the force that holds the product together.

Question 19

4 MARKS

Explain why solid sodium chloride does not conduct electricity, why molten sodium chloride does, and why copper conducts in both the solid and the molten state.

Question 20

4 MARKS

Two substances have the formulas SiO_2 and CO_2. Silicon dioxide melts above 1700 degrees Celsius; carbon dioxide sublimes at negative 78 degrees Celsius. Both contain a Group 14 element bonded to oxygen. Account for the difference.

Question 21

3 MARKS

Predict whether each of the following conducts electricity when molten, and give the reason in each case: magnesium chloride, iodine, aluminium.

> The bonding is not the answer. What the particles can do is the answer.

TWO LATTICES, BOTH STRONG, AND ONLY ONE CONDUCTS AS A SOLID

IONIC LATTICE, SODIUM CHLORIDE	METALLIC LATTICE, COPPER
Metal with non metal, electrons transfer.	Metal only, valence electrons delocalise.
Charged ions held in every direction.	Cations in a sea of mobile electrons.
High melting point, near 801 degrees C.	High melting point, near 1085 degrees C.
Conducts molten or dissolved, not solid.	Conducts in every state, always.
Brittle: like charges meet and repel.	Malleable: the sea reforms around a shift.

The difference is not bond strength. It is whether a charge carrier can move.

Conductivity in the solid state is the single fastest way to tell these two apart.

Figure 4 · Two lattices of similar strength. Only one has a charge carrier that moves in the solid.

4. Section III · Extended response

One question, 8 marks. Allow twenty minutes, including planning. Plan before you write. Two minutes spent listing the substances you will mention and the property you will link each one to will buy you more than two extra minutes of writing would. A response that covers three substances properly outscores one that mentions six.

The situation

The Kerrindal assay laboratory holds four solids on the shelf above the balance: copper metal, sodium chloride, silicon dioxide as quartz sand, and solid iodine.

A new technician is asked to identify each one using only a melting point apparatus, a conductivity meter and a beaker of water.

Question 22

8 MARKS

Explain how the bonding and structure of each solid gives rise to its melting point, its electrical conductivity in the solid and molten states, and its solubility in water. Use your explanation to describe the order in which the technician should carry out the three tests, and justify that order.

Plan here first. Four substances, three properties. A grid drawn beside this question beats a paragraph of prose planning.

Drill · The twelve-minute bonding drill

Run this once a week between now and the examination. It is short deliberately: the skill being trained is the speed at which you go from a formula to a prediction, and that improves by repetition, not by one long session on a Sunday.

MINUTES	WHAT YOU DO
0 to 2	Write down five formulas from memory, mixed: one ionic, one metallic, one covalent molecular, one covalent network, one with hydrogen bonding.
2 to 6	For each, write the bonding type and one sentence on why, naming the elements involved.
6 to 9	For each, predict melting point as high or low, and conductivity in the solid and molten states.
9 to 11	Check against the Topic Notes table. Mark each prediction right or wrong.
11 to 12	Write down the one you got wrong, and what you will check first next week.

Use formulas from the Kerrindal ore where possible: Cu_2S, PbS, $CaCO_3$, plus copper metal and water. Familiar substances make the question a test of reasoning rather than memory. **Twelve minutes a week beats three hours the night before.**

BEFORE YOU START, SIX THINGS THIS BOOKLET ASSUMES

Tick honestly. Any box you leave blank tells you which section to read twice.

- ☐ I name the bonding from the elements involved
- ☐ I explain melting points using forces, not bond strength
- ☐ I can write an electron configuration past argon
- ☐ I find relative atomic mass from abundances unprompted
- ☐ I know why solid ionic does not conduct but molten does
- ☐ I choose a separation technique from a property difference

An untidy tick is still an honest one. A tidy lie costs you a term.

Figure 5 · The six things this booklet assumes. Tick honestly, then reread what you left blank.

Audit · The explanation audit, run after you mark Section II

Tick only what your written answer did, not what you meant or what another five minutes would have produced.

- ☐ I named the bonding type before I described anything about the substance
- ☐ I said what the particles actually are: ions, molecules, atoms or cations in an electron sea
- ☐ I named the force that must be overcome, and did not say the bonds break
- ☐ I linked every property statement back to that force in the same sentence
- ☐ I distinguished the solid state from the molten state when I discussed conductivity
- ☐ I gave a reason for each prediction rather than a list of predictions
- ☐ I used the word because at least three times in a four mark answer

Interpreting your score

6 or 7: Your explanations are doing the work. Move on to timing and to Section III.

4 or 5: You know the chemistry and you are stating rather than linking. Rewrite two answers using the word because in every sentence. Then compare.

0 to 3: This is the uncomfortable band and it is also the most recoverable one. Every unticked box above is a habit, not a gap in knowledge. Pick the single one you miss most and make it automatic before you attempt another explanation question.

Extra practice · Questions 23 to 25

Three further items on the newer content of this module, outside the section totals and score bands. Do them after Section III; the worked solutions follow the marking guide.

Question 23

4 MARKS

Phosphorus trichloride, PCl_3, is a molecular liquid.

(a) Show that the Lewis structure of PCl_3 must show 26 valence electrons. **1 MARK**

(b) State the number of bonding pairs and the number of lone pairs in the whole molecule. **1 MARK**

(c) Name the shape of the molecule and explain why it takes that shape. **2 MARKS**

Question 24

3 MARKS

Silicon tetrafluoride, SiF_4, and ammonia, NH_3, both contain polar bonds. State which molecule is polar and which is non-polar, and explain the difference in terms of shape.

Question 25

3 MARKS

Ethanol, CH_3CH_2OH, and dimethyl ether, CH_3OCH_3, have the same molecular formula and so the same number of electrons. Ethanol has the higher boiling point. Explain why, naming the forces involved.

5. Worked solutions

Every question, with the reasoning shown and not just the answer.

Mark your work. There are 12 multiple choice answers and 9 short answer or calculation questions below, then the extended response. Where your working differs from the working here but your answer agrees, check whether your route would still have earned the method marks. A correct answer reached by a route a marker cannot follow should be identified now rather than in November.

Section I · Answers and reasoning

Q	ANSWER	BAND	WHY, AND WHAT THE DISTRACTORS WERE TESTING
1	B	Foundation	Copper(I) sulfide is a compound with a fixed composition, so it is a pure substance. A is filtered but still a solution of dissolved ions. C and D are mixtures. Filtered is not pure.
2	B	Foundation	The ore particles, including the calcite, are insoluble, so they stay on the paper while the water passes. Distillation separates by boiling point, chromatography by affinity, electrolysis is a chemical change, not a separation of a mixture.
3	C	Foundation	The 65 is the mass number, so protons plus neutrons. Copper is element 29, so 29 protons and 36 neutrons. D is the trap: it adds the mass number to the proton count.
4	B	Foundation	Copper has delocalised electrons that move in the solid. Sodium chloride has ions that are fixed in the lattice. Carbon dioxide and sulfur are molecular, with no mobile charge at all.
5	B	Consolidation	Calcium is element 20. The 4s subshell fills before 3d because it sits lower in energy at this point in the table. A fills 3d early, C puts four electrons in 4s, which holds only two, and leaves 3p two short, D is the argon count and leaves out two electrons.
6	B	Consolidation	Same shell across a period, so shielding is roughly constant while the nuclear charge rises. The valence electrons are pulled in harder. C reverses the comparison, A is false, D describes the wrong direction of the trend.
7	B	Consolidation	Lattice energy rises with the product of the ionic charges. Magnesium and oxide are both doubly charged, so the electrostatic attraction is about four times greater for a similar separation. C is the common wrong answer: lattice size is not the controlling factor here.
8	B	Consolidation	The bonded oxygen to hydrogen unit permits hydrogen bonding, which is the strongest of the intermolecular forces in this set. A is a distractor that is true of size but not of the boiling point order here, and C confuses bonds with the forces between molecules.
9	A	Consolidation	Weighted mean: 62.93 times 0.6915 plus 64.93 times 0.3085 gives 63.55. Option C is the unweighted mean of the mass numbers, which is what a student gets by averaging 63 and 65 and rounding. That distractor is a common slip.
10	A	Challenge	84.91 times 0.7217 plus 86.91 times 0.2783 gives 85.47. The answer must sit closer to the lighter isotope because that one is more abundant, which rules out B, C and D before any arithmetic, because 85.91 is the midpoint of the two isotope masses. Use that check first: it costs five seconds and it removes three of the four options.
11	B	Challenge	Each carbon atom forms three bonds, which leaves one electron per atom delocalised between the layers, and that electron carries charge. C is the attractive wrong answer: sliding layers explain lubrication, not conduction.
12	B	Challenge	X conducts molten but not solid and is brittle, which is ionic and nothing else. Y melts low and never conducts, which is covalent molecular. A covalent network would melt very high and still not conduct when molten, which is how C is eliminated.

Section II · Worked solutions

QUESTION 13 · HETEROGENEOUS MIXTURE · 3 MARKS

A heterogeneous mixture has a composition that is not uniform throughout, so a sample taken from one part of it differs from a sample taken from another part. The three minerals keep their own chemical identities and their own properties; nothing has combined chemically.

The observation. Separate solid phases are visible in the crushed ore, with different colours and grain shapes. A second acceptable observation is that two samples of equal mass taken from different parts of the same batch assay to different copper percentages, which is exactly why the laboratory grinds and cones a sample before weighing.

Where the three marks sit

One mark: composition is not uniform, and a sample is not representative of the whole.

One mark: the components keep their own properties and are not chemically combined.

One mark: a specific observation, not a restatement of the definition.

QUESTION 14 · SEPARATION ARITHMETIC · 5 MARKS

(a) m(calcite) = 0.312 × 250.0 = 78.0 g

(b) The dried solid weighs 46.8 g but 2.4 g of that is filter fibre, so the calcite recovered is 46.8 minus 2.4, which is 44.4 g.

percentage recovered = 44.4 / 78.0 × 100 = 56.9 per cent

(c) Filtration works because calcite is insoluble in water and the paper retains it while the water passes through. Distillation would not work: it separates by boiling point and both solids stay behind when the water evaporates, so nothing is separated from anything.

The mark that gets dropped

Most students who lose a mark here subtract the filter fibre from 78.0 rather than from 46.8. Read the stem again: the fibre was carried through into the weighing, so it is part of the 46.8, not part of the original sample.

QUESTION 15 · ELECTRON CONFIGURATION OF IRON AND ITS ION · 4 MARKS

Iron is element 26.

Fe: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$

Fe^{2+}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$

Which electrons leave first. The two 4s electrons are removed, not the 3d electrons. This surprises students because 4s filled first. The resolution is that filling order and removal order are answering different questions. The 4s subshell is lower in energy while the 3d subshell is empty, so it fills first. Once the 3d subshell is occupied, the 4s electrons sit further from the nucleus and are more shielded, so they are the ones a chemical change removes.

Say this sentence and the mark is yours

The 4s electrons fill first and are removed first, because once 3d is occupied the 4s electrons are the outermost.

QUESTION 16 · ABUNDANCE WORKED BACKWARDS · 3 MARKS

Let x be the fractional abundance of the heavier isotope, mass 11.01. Then the abundance of the lighter one is 1 minus x.

10.01(1 − x) + 11.01x = 10.81

10.01 + 1.00x = 10.81

x = 0.800, so the heavier isotope is 80.0 per cent abundant and the lighter is 20.0 per cent.

The check that takes five seconds. 10.81 sits much closer to 11.01 than to 10.01, so the heavier isotope must be the more abundant one. Any answer below 50 per cent is wrong before you check the algebra. Do this check on every abundance question, in both directions.

QUESTION 17 · PERCENTAGE COPPER IN CHALCOCITE · 3 MARKS

$M(Cu_2S)$ = 2(63.55) + 32.07 = 159.17 g/mol

per cent Cu = 2(63.55) / 159.17 × 100 = 127.10 / 159.17 × 100 = 79.85 per cent

The judgement. No. Pure chalcocite is 79.85 per cent copper by mass, so an ore assaying 18.0 per cent copper cannot be pure chalcocite. It is a mixture in which chalcocite is one component among gangue minerals such as calcite, which is exactly what the Kerrindal plant log describes.

Where the third mark sits

The third mark is for the comparison and the conclusion, not for the arithmetic. A response that computes 79.85 and stops has answered calculate, not the question asked.

QUESTION 18 · SODIUM AND CHLORINE · 3 MARKS

Balanced equation

$$2Na\ (s) + Cl_2\ (g) \rightarrow 2NaCl\ (s)$$

Each sodium atom has one valence electron and loses it, becoming Na^+. Each chlorine atom gains one electron, and since chlorine exists as Cl_2, one molecule takes two electrons in total and forms two Cl^- ions.

Half equations, if you prefer to show the transfer explicitly:

$$Na \rightarrow Na^+ + e^-$$

$$Cl_2 + 2e^- \rightarrow 2Cl^-$$

The force. The product is held together by strong electrostatic attraction between oppositely charged ions, acting in every direction through a three dimensional lattice. This is ionic bonding. Note the wording: the attraction is between ions, not between one sodium and one particular chloride. There is no NaCl molecule.

QUESTION 19 · CONDUCTIVITY IN THREE CASES · 4 MARKS

Solid sodium chloride does not conduct. Charged particles are present, which is the half of the answer everyone writes. The reason it does not conduct is that those ions are held in fixed positions in the lattice and cannot move to an electrode. A conductor needs a charge carrier that is both charged and mobile.

Molten sodium chloride conducts. Melting supplies enough energy to overcome the electrostatic attractions holding the lattice together. The ions are now free to move through the liquid, so they carry charge towards the electrodes.

Copper conducts in both states. In a metallic lattice the valence electrons are delocalised over the whole structure rather than belonging to any one atom. They are mobile in the solid, so no melting is required. Melting a metal frees the cations to move as well, but the conduction was never waiting on that.

The sentence that separates a 4 from a 2

Charged and mobile. Both words, every time. Sodium chloride solid has the first and not the second, which is the entire explanation.

QUESTION 20 · SILICON DIOXIDE AGAINST CARBON DIOXIDE · 4 MARKS

The formulas look similar and the structures are not.

Carbon dioxide is covalent molecular. Carbon forms two double bonds to oxygen and the molecule is complete and discrete. Between separate CO_2 molecules there are only weak dispersion forces, because the molecule is linear and its two bond dipoles cancel. Subliming it separates molecules from one another, which requires very little energy, so it happens at negative 78 degrees Celsius.

Silicon dioxide is a covalent network. Silicon is larger than carbon and does not form stable double bonds to oxygen in this setting, so each silicon bonds singly to four oxygens and each oxygen bridges two silicons. The result is one continuous lattice of covalent bonds rather than separate molecules. Melting it means breaking strong covalent bonds throughout the structure, which is why the melting point exceeds 1700 degrees Celsius.

The controlling idea. Melting point is set by what has to be overcome during the change of state. For a molecular solid that is an intermolecular force. For a network solid it is a covalent bond. The two differ by roughly a factor of a hundred in energy, and that factor is the whole answer.

QUESTION 21 · THREE PREDICTIONS · 3 MARKS

SUBSTANCE	CONDUCTS WHEN MOLTEN?	REASON
Magnesium chloride	Yes	Ionic. Melting breaks down the lattice and frees Mg^{2+} and Cl^- ions to move and carry charge.
Iodine	No	Covalent molecular. Melting separates I_2 molecules from one another. The molecules are neutral, so there is no charge carrier in any state.
Aluminium	Yes	Metallic. Delocalised electrons carry charge, and they do so in the solid as well, so melting is not what makes it conduct.

Before you turn the page

A warning about aluminium. The question asked about the molten state, and aluminium conducts there. A response that says yes and stops has answered it. A response that adds the words and in the solid state too has shown the marker it understands why, which matters when the next question asks you to distinguish metallic from ionic.

Section III · Worked solution and marking guide

QUESTION 22 · THE FOUR SOLIDS ON THE SHELF · 8 MARKS

This response is set out as four substances, then the testing order. Notice that the properties are never listed on their own: each one is attached to the structure in the same sentence.

COPPER, METALLIC BONDING

Copper atoms release their valence electrons into a delocalised sea, leaving a lattice of cations. The attraction between the cations and the electron sea is strong and acts throughout the structure, so the melting point is high, near 1085 degrees Celsius. Because the electrons are mobile in the solid, copper conducts as a solid and as a liquid. It does not dissolve in water: there is no interaction with water molecules strong enough to pull a metal cation out of the electron sea.

SODIUM CHLORIDE, IONIC BONDING

Electrons transfer from sodium to chlorine, giving Na^+ and Cl^- ions held in a lattice by electrostatic attraction in every direction. Breaking a large number of these attractions requires substantial energy, so the melting point is high, at 801 degrees Celsius. It does not conduct as a solid, because the ions are fixed, but it conducts when molten, because they are then free to move. It dissolves in water, because the polar water molecules attract the ions strongly enough to overcome the lattice, and the resulting solution conducts.

SILICON DIOXIDE, COVALENT NETWORK

Each silicon is covalently bonded to four oxygens and each oxygen bridges two silicons, giving one continuous covalent lattice. Melting requires breaking covalent bonds throughout the solid, so the melting point exceeds 1700 degrees Celsius, the highest of the four. There are no ions and no delocalised electrons, so it does not conduct in any state. It does not dissolve in water, because water cannot supply the energy to break covalent bonds.

IODINE, COVALENT MOLECULAR

Iodine exists as discrete I_2 molecules. The covalent bond within each molecule is strong, but the forces between molecules are dispersion forces only, and these are weak. Melting separates molecules without touching a covalent bond, so the melting point is low, at 114 degrees Celsius, the lowest of the four. It does not conduct in any state, because the molecules are neutral. It is only slightly soluble in water, because water is polar and iodine is not, so the water to water hydrogen bonds are not worth breaking to accommodate it.

THE ORDER OF TESTING, AND WHY

Test conductivity of the solid first. It is non destructive, it takes seconds, and it isolates the copper immediately, because copper is the only one of the four that conducts as a solid.

Test solubility in water second, using a small sample. This isolates the sodium chloride, which dissolves readily, while the other two remaining solids do not. A conductivity check on that solution confirms it, because a solution of ions conducts and there is no other candidate that would.

Test melting point last, and only on the two remaining solids if confirmation is wanted. It is the slowest test, it consumes the sample, and one of the two candidates melts above 1700 degrees Celsius, which a school apparatus cannot reach. That last point is itself the evidence: an apparatus that fails to melt the sample has identified the silicon dioxide, and the one that melted at 114 degrees Celsius is the iodine.

The justification in one sentence. Run the fast, non destructive, discriminating tests first and the slow, destructive one last, so that each test is performed on the smallest remaining set of candidates.

Marking guide, Question 22

Use this on your own response before you look at anything else. Mark it as a marker would: award what is written, not what you intended.

MARKS	CRITERIA
7 to 8	Correctly identifies the bonding and structure in all four solids. Explains melting point, conductivity in both states and solubility for each, with every property linked explicitly to the structure. Proposes a testing order and justifies it by reference to discrimination, speed or destructiveness. Uses correct terminology throughout, including the distinction between breaking intermolecular forces and breaking covalent bonds.
5 to 6	Identifies the bonding in all four solids correctly. Explains most properties with a link to structure, though one or two properties are stated rather than explained. Proposes a sensible testing order with a partial justification.
3 to 4	Identifies the bonding in most of the solids. Properties are largely stated with limited linking to structure. A testing order is given with little or no justification, or the order is not internally consistent.
1 to 2	Some correct identification of bonding or some correct property statements, with little explanation. May confuse covalent molecular with covalent network, which is the most common error in this question.

The two things that move a 5 to a 7

One: say which force is overcome during the change of state, for every substance. Not that the melting point is high, but what has to break for it to melt.

Two: justify the testing order by a property of the test, such as speed or whether it destroys the sample, rather than by the order you happened to think of them in.

> Covalent molecular and covalent network are not two names for one idea. Write the word network or the word molecular every time and half this topic's errors disappear.

Module 1, tracked over the term

Date each attempt. Record the section, the mark and the single change you will make.

Compare a mark from six weeks ago with a current mark to measure improvement.

Make one change per attempt.

Extra practice · Worked solutions to questions 23 to 25

QUESTION 23 · LEWIS STRUCTURE AND SHAPE OF PCl_3 · 4 MARKS

(a) Phosphorus is in Group 15 with 5 valence electrons and each chlorine is in Group 17 with 7, so the total is 5 + 3 × 7 = 26 electrons.

(b) Three P-Cl single bonds use 3 × 2 = 6 electrons, so 26 minus 6 = 20 electrons remain. Those make 10 lone pairs, one on phosphorus and three on each chlorine. The molecule has **3 bonding pairs and 10 lone pairs**.

(c) Phosphorus has four electron regions, three bonding pairs and one lone pair. They repel and take a tetrahedral arrangement, but only three of the four positions hold an atom, so the shape is **trigonal pyramidal**. The lone pair repels the bonding pairs more strongly than they repel each other, so the angle is a little less than 109.5 degrees.

QUESTION 24 · POLAR BONDS, NON-POLAR MOLECULE · 3 MARKS

Both molecules have polar bonds, because fluorine is more electronegative than silicon and nitrogen is more electronegative than hydrogen. SiF_4 is tetrahedral with four identical bonds, so the four bond dipoles point symmetrically and cancel: **SiF_4 is non polar**. NH_3 is trigonal pyramidal, so its three bond dipoles all tilt the same way and do not cancel: **NH_3 is polar**. One mark for each classification and one for tying the difference to shape.

QUESTION 25 · ETHANOL AND DIMETHYL ETHER · 3 MARKS

With the same formula the two molecules have the same number of electrons, so their dispersion forces are about equal. Ethanol has hydrogen bonded to oxygen, so its molecules hydrogen bond to each other. Dimethyl ether has no O-H group, so it has only dipole-dipole and dispersion forces. More energy is needed to overcome the intermolecular forces in ethanol, so it has the higher boiling point. The covalent bonds inside the molecules do not break on boiling.

DATE	SECTION AND MARK	THE ONE CHANGE I AM MAKING

Fill one row every time you sit a set. A tracker with three rows in it is worth more than a perfect one you never started, because the pattern you are looking for only appears across attempts.

About this resource

MA99 EDUCATION

Scope

NSW Chemistry, Year 11. Written to the NSW Chemistry Stage 6 Syllabus (2017), Module 1, for students sitting the HSC in 2028. A new Chemistry syllabus is first examined in HSC 2029. Every worked context uses the invented Kerrindal mine, its assay laboratory and the other invented sites of the MA99 Year 11 suite, with every other context labelled where it is hypothetical, and every number was recomputed from its inputs before printing.

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