MA99 EDUCATION

Chemistry: Practice Paper 4 · Modules 1 to 4

04

NSW CHEMISTRY STAGE 6 SYLLABUS 2017 FOR HSC 2028

1. General instructions

Read this page before you start the clock

Reading time: 5 minutes. Working time: 3 hours.

Total marks: 100.

A calculator, the NESA Chemistry data sheet, the formulae sheet and the Periodic Table may be used. Section I, 20 marks. Attempt all 20 multiple choice questions. Allow about 35 minutes.

Section II, 80 marks. Attempt all questions. Show all working, including the formula, the substitution and the answer with its unit. Allow about 2 hours and 25 minutes.

Sit this school-style paper in one sitting, under time. A paper done in pieces across a week measures your knowledge. A paper done in three hours measures what you can produce in three hours, and the second number is the one the examination reports. Most capable candidates lose their remaining marks to the clock, not to the chemistry.

Where the marks are. All four modules are tested and many questions span several, which mirrors the way the Preliminary course allocates its indicative hours: Module 1 with Module 2, and Module 3 with Module 4, 60 hours to each pair. If one module is weak, it costs you about a quarter of the paper and no amount of strength elsewhere recovers it.

Use the data sheet from the first minute. The NESA periodic table gives atomic masses, and the NESA data sheet gives Avogadro's constant, the molar volume of a gas, the specific heat capacity of water, solubility constants and standard potentials. Candidates who try to recall them lose time and introduce errors that the sheet in front of them would have prevented. The data sheet lists solubility constants, not solubility rules, so learn the rules in Module 3.

Modules covered. Module 1 Properties and Structure of Matter, Module 2 Introduction to Quantitative Chemistry, Module 3 Reactive Chemistry, Module 4 Drivers of Reactions. Every context in this paper is drawn from the Kerrindal Works, the minerals and water processing plant used across the whole MA99 Chemistry suite, so no candidate is advantaged by having seen a particular site.

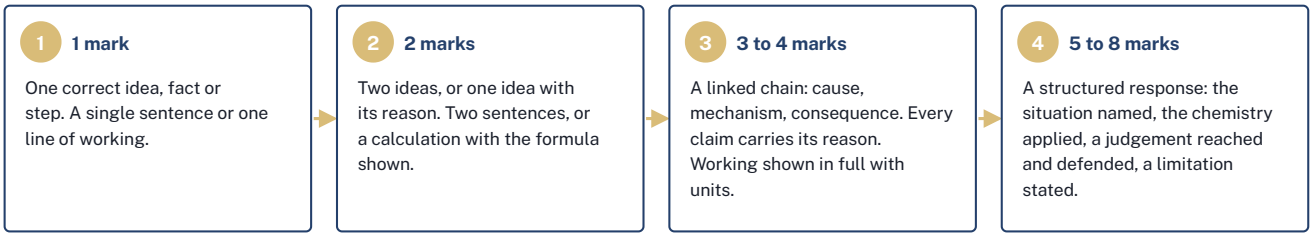


Figure 1 · What each mark value is asking you to produce. Check your answer length against this before you write.

2. Section I · Multiple choice

20 marks. Attempt all questions. Allow about 35 minutes. Select the alternative (A), (B), (C) or (D) that best answers each question. Mark your answers in the grid below, then transfer nothing: this grid is your answer sheet.

Question 1

1 MARK

Which of the following is a pure substance?

A Kerrindal river water after filtration
B Copper(I) sulfide, Cu_2S
C The crushed ore delivered to the mill
D Air drawn into the roaster

Question 2

1 MARK

An atom is described as ^{65}Cu. Copper is element 29. How many neutrons does this atom contain?

A 29
B 36
C 65
D 94

Question 3

1 MARK

Which substance conducts electricity in the solid state?

A Sodium chloride
B Copper
C Solid carbon dioxide
D Silicon dioxide

Question 4

1 MARK

Across Period 3 from sodium to chlorine the first ionisation energy increases. This is mainly because

A the number of occupied shells increases
B the nuclear charge increases while the shielding stays about the same
C the atoms become less metallic in character
D the electrons are added to a new shell each time

Question 5

1 MARK

Which of the following substances has hydrogen bonding between its molecules?

A Methane, CH_4
B Ethanol, C_2H_6O
C Carbon dioxide, CO_2
D Butane, C_4H_{10}

Question 6

1 MARK

Which statement about a covalent network solid such as silicon dioxide is correct?

A It melts at a low temperature because the molecules are separate
B It conducts electricity when molten because ions become mobile
C It melts at a very high temperature because covalent bonds must be broken
D It dissolves readily in water to give a conducting solution

Question 7

1 MARK

The percentage by mass of copper in chalcocite, Cu_2S, is closest to

A 39.9 per cent
B 66.5 per cent
C 79.9 per cent
D 88.2 per cent

Question 8

1 MARK

Which quantity is equal to the number of particles in one mole?

A 6.022×10^{23}
B 24.79
C 6.022×10^{-23}
D 1.008

Question 9

1 MARK

The number of moles in 5.00 g of calcium carbonate, $CaCO_3$, is closest to

A 0.0500 mol
B 0.500 mol
C 5.00 mol
D 20.0 mol

Question 10

1 MARK

In the compound sodium sulfate, Na_2SO_4, the oxidation number of sulfur is

A +2
B +4
C +6
D +8

Question 11

1 MARK

0.250 mol of sodium hydroxide is dissolved and made up to 500.0 mL. The concentration of the solution is

A 0.125 mol/L
B 0.250 mol/L
C 0.500 mol/L
D 2.00 mol/L

Question 12

1 MARK

Which pair of reactants will produce a visible precipitate when mixed?

A Sodium nitrate and potassium chloride
B Silver nitrate and sodium chloride
C Sodium chloride and potassium nitrate
D Potassium nitrate and sodium sulfate

Question 13

1 MARK

At 25 degrees Celsius and 100 kilopascals the molar volume of a gas is 24.79 L/mol. The volume occupied by 0.150 mol of sulfur dioxide is closest to

A 1.65 L
B 3.72 L
C 16.5 L
D 165 L

Question 14

1 MARK

A strip of zinc is placed in a solution of copper(II) sulfate. The zinc becomes coated with copper. This shows that

A copper is more reactive than zinc
B zinc is more reactive than copper
C the two metals have equal reactivity
D no electron transfer has occurred

Question 15

1 MARK

In the reaction $Fe \rightarrow Fe^{2+} + 2e^-$, the iron has been

A reduced, because it has lost electrons
B oxidised, because it has lost electrons
C reduced, because it has gained electrons
D oxidised, because it has gained electrons

Question 16

1 MARK

Which observation indicates that a chemical reaction has taken place rather than a physical change?

A A solid dissolves in water
B A liquid boils and turns to vapour
C A gas is evolved and a new insoluble solid forms
D A solution is diluted and becomes paler

Question 17

1 MARK

A reaction has a negative enthalpy change. This means the reaction

A absorbs energy from the surroundings and the surroundings cool
B releases energy to the surroundings and the surroundings warm
C has a positive entropy change
D proceeds at a faster rate

Question 18

1 MARK

Burning a fuel raises the temperature of 100.0 g of water by 6.50 degrees Celsius. Taking the specific heat capacity of water as 4.18 J/g/K, the heat absorbed by the water is closest to

A 272 J
B 652 J
C 2720 J
D 27200 J

Question 19

1 MARK

Which change is accompanied by the largest increase in entropy?

A Water vapour condensing to liquid water
B A solid carbonate decomposing to a solid oxide and a gas
C Two gases reacting to form one gas
D A solution being cooled from 30 to 10 degrees Celsius

Question 20

1 MARK

A reaction is endothermic and has a positive entropy change. This reaction is

A spontaneous at all temperatures
B spontaneous only at high temperatures
C spontaneous only at low temperatures
D never spontaneous at any temperature

2.1 Section I answer grid

Fill this in as you go, not at the end. A candidate who leaves the grid to the last five minutes is the candidate who runs out of them.

Q	1	2	3	4	5	6	7	8	9	10
Q	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**

3. Section II · Short answer and extended response

80 marks. Attempt all questions. Allow about 2 hours and 25 minutes. Show all working, including the formula, the substitution and the answer with its unit. Give each answer to a sensible number of significant figures. Where a question asks for a balanced equation, include state symbols.

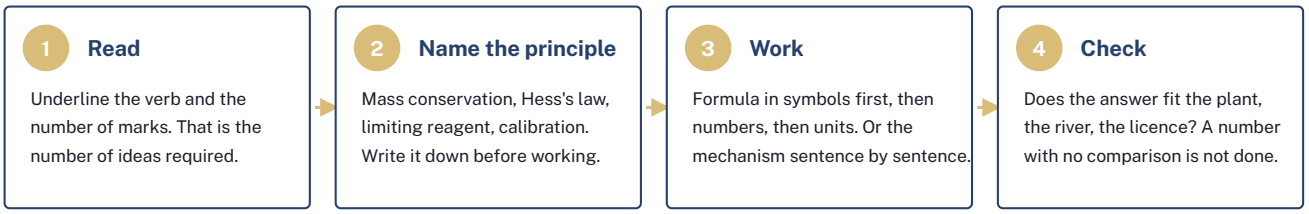


Figure 2 · The same four moves on every Section II item. Read, name the principle, work, then check the answer against the context.

About two minutes a mark. There are 22 questions in this section. A 3 mark question that has taken you nine minutes is a question you should have left and come back to. Mark it beside the number on your own paper and move on.

Modules 1 and 2 · Structure and Moles

Question 21

2 MARKS

The assay laboratory receives a 40.00 g sample of Kerrindal copper concentrate that is 82.5 per cent chalcocite, Cu_2S, by mass. The concentrate is roasted in excess oxygen to give copper(I) oxide and sulfur dioxide. Write the balanced equation for the roasting reaction, including state symbols, and calculate the mass of chalcocite in the sample.

Question 22

2 MARKS

Using your answer to question 21, calculate the amount, in mole, of chalcocite present in the sample.

Question 23

3 MARKS

Calculate the volume of sulfur dioxide produced by the roast in question 21, measured at 25 degrees Celsius and 100 kilopascals.

Question 24

4 MARKS

Copper has two stable isotopes, ^{63}Cu of isotopic mass 62.93 and ^{65}Cu of isotopic mass 64.93. The relative atomic mass of copper is 63.55. Calculate the percentage abundance of each isotope, and explain in one sentence how you could tell before any arithmetic which isotope is the more abundant.

Question 25

5 MARKS

Compare the bonding and structure of copper metal and of solid carbon dioxide, and use your comparison to account for the difference in their melting points and in their electrical conductivity.

Module 2 · Introduction to Quantitative Chemistry

Question 26

3 MARKS

The Kerrindal calciner roasts calcite. A 250.0 g charge of pure calcium carbonate is heated until decomposition is complete, giving calcium oxide and carbon dioxide. Write the balanced equation and calculate the mass of calcium oxide produced.

Question 27

2 MARKS

Calculate the percentage of the original charge mass in question 26 that is lost as gas, and explain why the plant uses that figure to check whether the calciner has run to completion.

Question 28

3 MARKS

Define the term limiting reagent, and explain why the assay laboratory adds barium chloride in excess when it determines sulfate by precipitation.

Question 29

3 MARKS

A technician standardises the plant sulfuric acid. A 25.00 mL pipetted aliquot of 0.100 mol/L sodium hydroxide is titrated against the acid. The titres recorded are 22.85, 21.30, 21.40 and 21.35 mL. Identify which titres are concordant and calculate the mean titre, justifying which titres you excluded.

Question 30

4 MARKS

For the titration in question 29, write the balanced equation and calculate the concentration of the sulfuric acid.

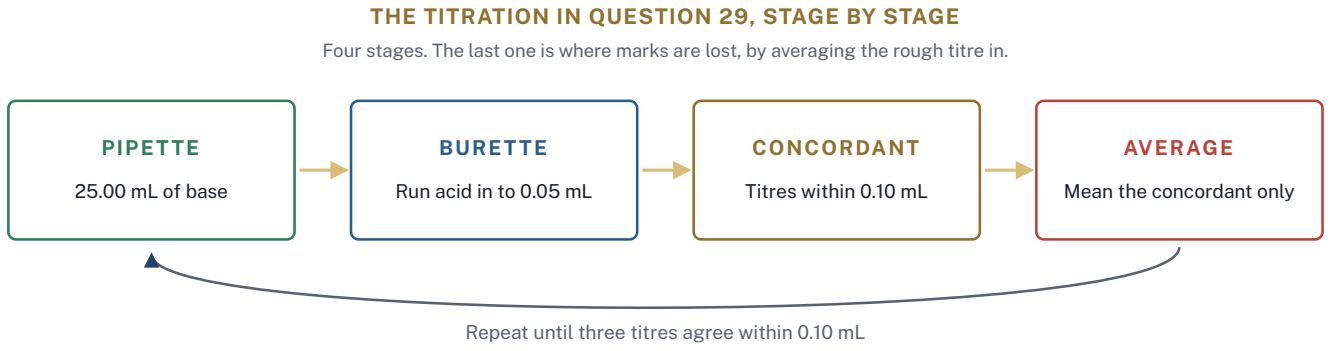


Figure 3 · The titration in question 29, in four stages. Only the concordant titres are averaged.

Question 31

3 MARKS

A student reports the concentration of a solution as 0.058546 mol/L after measuring a volume to four significant figures and a concentration to three. Assess this reported answer.

Module 3 · Reactive Chemistry

Question 32

3 MARKS

A 3.27 g strip of zinc is dropped into 400.0 mL of 0.100 mol/L sulfuric acid. Write the balanced equation and the two half equations for this reaction.

Question 33

2 MARKS

For the reaction in question 32, determine which reactant is limiting, showing your working.

Question 34

2 MARKS

Calculate the volume of hydrogen produced in question 32, measured at 25 degrees Celsius and 100 kilopascals.

Question 35

4 MARKS

Magnesium ribbon is placed in copper(II) sulfate solution and a brown solid forms on the ribbon. Write the balanced ionic equation, identify the species oxidised and the species reduced, and explain how the activity series predicts this outcome.

Question 36

4 MARKS

Outline two tests the assay laboratory could use to distinguish a carbonate from a sulfate in a solid sample, stating the reagent used and the observation expected in each case.

Question 37

4 MARKS

The licence return line is sampled. A 175.0 mL sample of treated water is acidified and excess barium chloride solution is added. The precipitate is filtered, dried and weighed at 0.4382 g. Calculate the sulfate concentration of the treated water in milligrams per litre, and state one reason the sample is acidified first.

Module 4 · Drivers of Reactions

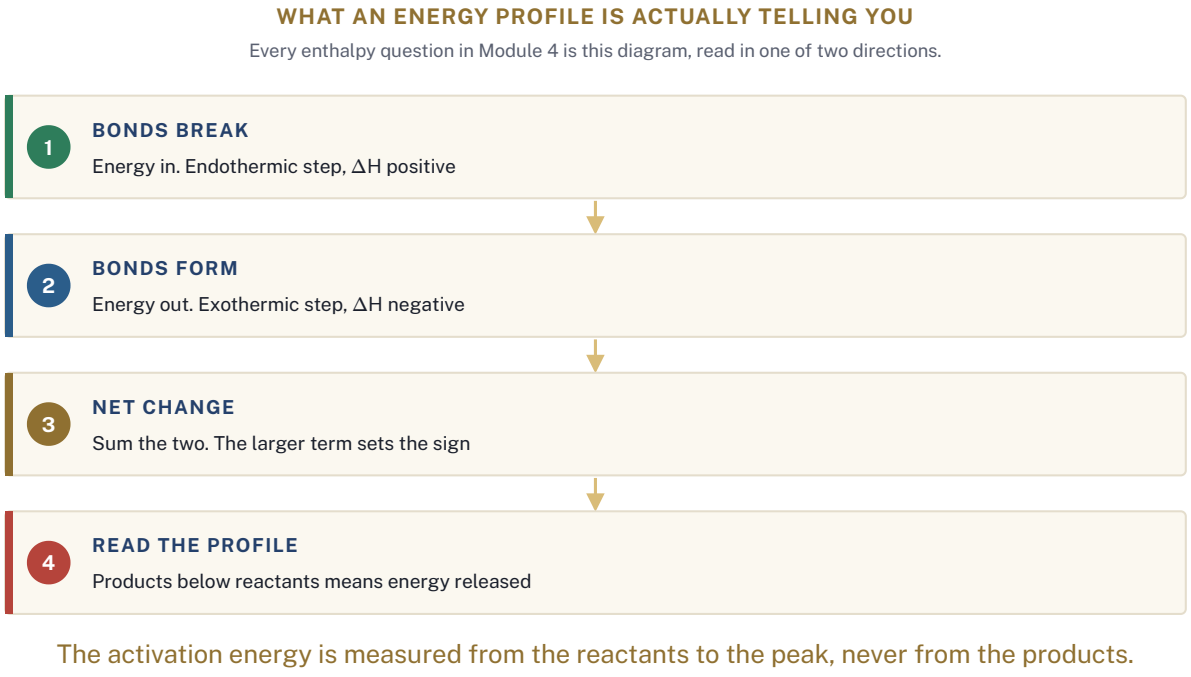


Figure 4 · The two steps inside every enthalpy change. Question 39 asks you to find the net change of this diagram from a measurement.

Question 38

4 MARKS

Distinguish between the enthalpy change and the entropy change of a reaction, and state what each contributes to whether a reaction is spontaneous.

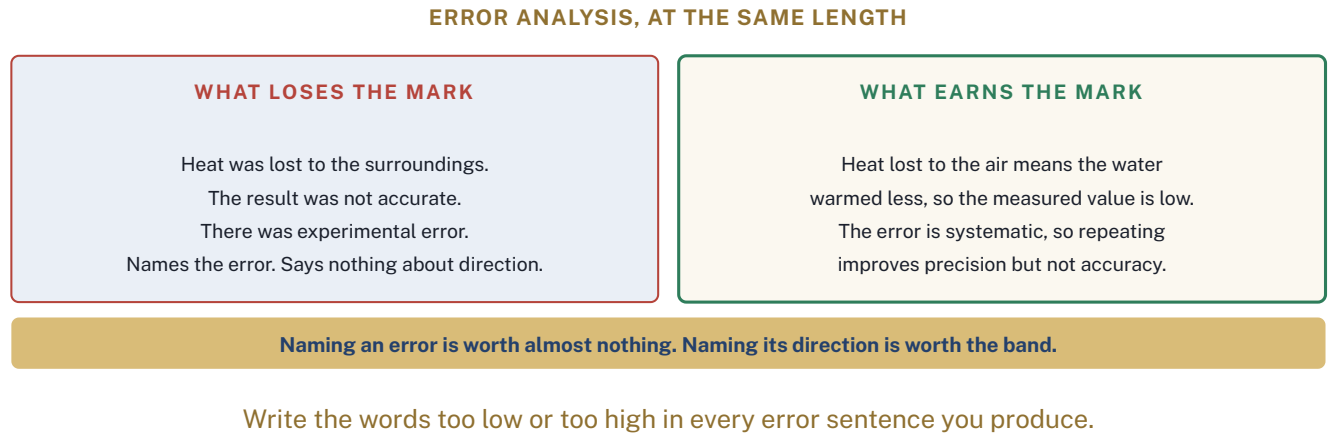


Figure 5 · Two error sentences of the same length. Only one names a direction.

Question 39

5 MARKS

In the Kerrindal laboratory a spirit burner is used to heat water in a metal can. Burning 0.412 g of ethanol raises the temperature of 150.0 g of water by 11.4 degrees Celsius. Take the specific heat capacity of water as 4.18 J/g/K. Write the balanced equation for the complete combustion of ethanol, then calculate the molar enthalpy of combustion from this data.

Question 40

3 MARKS

The accepted molar enthalpy of combustion of ethanol is 1367 kJ/mol released. Compare your answer to question 39 with it and account for the difference, stating the direction in which each source of error acts.

Extended response

Question 41

8 MARKS

The Kerrindal jetty piles are made of iron and are bolted with copper fittings. They stand permanently in river water. Explain, using half equations, why the iron corrodes faster than iron alone would, and assess two measures the plant could use to control it.

Plan first. Eight marks is about a page. Two minutes of planning against sixteen minutes of writing is the ratio that produces a structured response rather than a list.

Question 42

7 MARKS

A 2.500 g sample of Kerrindal ore is treated with excess hydrochloric acid. The carbonate present decomposes and the sample loses 0.4136 g as carbon dioxide. Calculate the percentage of calcite, $CaCO_3$, in the ore, then explain how the quantitative result and the reactivity of the carbonate together justify the plant's decision to leach the ore with acid before roasting it.

> Two extended responses, fifteen marks. That is 15 per cent of the paper sitting in two questions, and candidates leave them until nine minutes remain.

4. Solutions and marking guidelines

Every question worked, with the reasoning shown and not only the answer.

Do not open this section until you have written something for every question. A solution read before your own attempt produces the feeling of understanding and none of the evidence. A solution read after your attempt tells you what you personally do instead, which is the only thing you are able to change between now and the examination.

Mark to the criteria, not to your memory of the lesson. Paper 4 carries 100 marks. Record your Section I total and your Section II total separately. Candidates who are losing marks in Section I have a recall problem; candidates who are losing them in Section II usually know the chemistry and are not writing the link sentence that carries the mark.

4.1 Section I · Answers and reasoning

Q	ANSWER	WHY THAT ONE, IN A LINE
1	B	A compound has a fixed composition, so copper(I) sulfide is pure. Filtered river water still carries dissolved ions, and the ore and the air are mixtures.
2	B	The 65 is the mass number, protons plus neutrons. Copper has 29 protons, so 65 minus 29 gives 36 neutrons. Option D adds the two instead of subtracting.
3	B	Copper has delocalised electrons that move through the solid. The ions in solid sodium chloride are fixed, and the other two have no mobile charge at all.
4	B	Nuclear charge rises across a period while the electrons enter the same shell, so shielding is roughly constant and the valence electrons are held harder.
5	B	Ethanol carries a hydroxyl group, so hydrogen bonded to oxygen. The other three are hydrocarbons or have no hydrogen bonded to nitrogen, oxygen or fluorine.
6	C	A covalent network is one continuous lattice of covalent bonds, so melting it breaks covalent bonds. It has no ions and no delocalised electrons, so it never conducts.
7	C	2(63.55) divided by 159.17, times 100, gives 79.85 per cent. Option A is the answer obtained by using one copper atom rather than two.
8	A	Avogadro constant is 6.022 times ten to the power 23 per mole. Option B is the molar volume of a gas and option C is the same number with the sign of the exponent reversed.
9	A	n = m / M = 5.00 / 100.09, which is 0.0500 mol. Option B is the result of dividing by ten rather than by the molar mass.
10	C	Sodium is +1 each and oxygen is negative 2 each. For the compound to be neutral, 2 plus x plus 4 times negative 2 equals zero, so x is +6.
11	C	c = n / V = 0.250 / 0.5000 = 0.500 mol/L. Option B reports the amount of solute, 0.250 mol, as if it were the concentration.
12	B	Silver chloride is insoluble, so it precipitates. All nitrates are soluble and the sodium and potassium salts in the other options are soluble as well.
13	B	V = n Vm = 0.150 times 24.79, which is 3.72 L. Option D is the result of dividing by the amount rather than multiplying.
14	B	Zinc displaces copper, so zinc gives up electrons more readily and sits above copper in the activity series. Option A reverses the conclusion.
15	B	Electrons appear on the right of the half equation, so they have been lost. Loss of electrons is oxidation. Option A names the wrong process for a correct observation; D gives the right process with the wrong reason.
16	C	A new substance has formed: an evolved gas and an insoluble solid are both products. Dissolving, boiling and diluting are all physical changes.
17	B	A negative enthalpy change means energy leaves the system, so the surroundings gain it and warm. Sign and entropy are independent, which rules out option C.

Q	ANSWER	WHY THAT ONE, IN A LINE
18	C	q = m c ΔT = 100.0 times 4.18 times 6.50, which is 2717 J, closest to 2720 J. Option A drops a factor of ten in the mass.
19	B	One solid becoming a solid plus a gas creates a gas where there was none, which is the largest increase in disorder available in this list.
20	B	The enthalpy term opposes and the entropy term favours. Raising the temperature increases the weight of the entropy term, so the reaction becomes spontaneous above a crossover temperature.

4.2 Section II · Worked solutions

QUESTION 21 · EQUATION AND MASS OF CHALCOCITE · 2 MARKS

$2Cu_2S\ (s) + 3O_2\ (g) \rightarrow 2Cu_2O\ (s) + 2SO_2\ (g)$

Checked: four copper and two sulfur on each side, six oxygen on each side.

$m(Cu_2S) = 0.825 \times 40.00 = 33.00$ g

Marks

1 mark: correct formulas on both sides and the equation balanced. 1 mark: the mass of chalcocite, with its unit.

QUESTION 22 · AMOUNT OF CHALCOCITE · 2 MARKS

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

$n = m / M = 33.00 / 159.17 = 0.2073$ mol

Show the molar mass as a sum. A marker can follow a sum and award the mark even when the division that follows it slips. A quoted number offers nothing to follow.

QUESTION 23 · VOLUME OF SULFUR DIOXIDE · 3 MARKS

From the equation, 2 mol of chalcocite gives 2 mol of sulfur dioxide, a ratio of 1 to 1.

$n(SO_2) = 0.2073$ mol

$V = n \times Vm = 0.2073 \times 24.79 = 5.14$ L at 25 degrees Celsius and 100 kilopascals.

Marks

1 mark: the mole ratio stated, with the equation named as its source. 1 mark: the molar volume applied correctly.

1 mark: the answer with its unit and the conditions attached.

The check that costs two lines. The sample holds 2 × 0.2073 = 0.4146 mol of copper, or 26.35 g. That is 65.9 per cent copper in the concentrate, consistent with a copper sulfide concentrate and a confirmation that the mole figure is right before the gas volume is built on it.

QUESTION 24 · ISOTOPIC ABUNDANCE · 4 MARKS

Let x be the fractional abundance of ^{63}Cu. Then the abundance of ^{65}Cu is 1 − x.

$62.93x + 64.93(1 - x) = 63.55$

$64.93 - 2.00x = 63.55$, so $2.00x = 1.38$ and $x = 0.690$

Copper 63 is 69.0 per cent abundant and copper 65 is 31.0 per cent abundant.

The five second check. 63.55 sits much closer to 62.93 than to 64.93, so the lighter isotope must be the more abundant one. Any answer that makes copper 65 the majority isotope is wrong before the algebra is checked. Do this in both directions on every abundance question.

Marks

1 mark: sets up the weighted mean with one unknown.

2 marks: solves correctly for both abundances as percentages.

1 mark: the qualitative check, stated as a reason rather than as an assertion.

QUESTION 25 · COPPER AND SOLID CARBON DIOXIDE · 5 MARKS

Copper. Metallic bonding. A lattice of copper cations in a sea of delocalised valence electrons, held by the electrostatic attraction between the two. Melting must overcome that attraction throughout the lattice, which takes a great deal of energy, so the melting point is high at 1085 degrees Celsius. The delocalised electrons are free to move in the solid, so copper conducts as a solid and as a liquid.

Solid carbon dioxide. Covalent molecular. Discrete CO_2 molecules with strong covalent bonds inside each molecule and only weak dispersion forces between them. Melting or subliming separates molecules from one another and so overcomes only those weak forces, not the covalent bonds, which is why it sublimes at negative 78 degrees Celsius. There are no ions and no delocalised electrons, so it never conducts.

The controlling principle. A melting point is set by the forces that must be overcome during the change of state, and conductivity is set by whether a mobile charge carrier exists. Both properties follow from the particles present.

The sentence that separates the bands

Subliming carbon dioxide does not break a single covalent bond. Writing that sentence is worth a mark on its own, and many candidates write the opposite.

QUESTION 26 · THE CALCINER · 3 MARKS

$CaCO_3$ (s) $\rightarrow$ CaO (s) + CO_2 (g)

M($CaCO_3$) = 40.08 + 12.01 + 3(16.00) = 100.09 g/mol

n($CaCO_3$) = 250.0 / 100.09 = 2.498 mol

The ratio is 1 to 1, so n(CaO) = 2.498 mol.

m(CaO) = 2.498 × 56.08 = 140.1 g

Marks

1 mark: the balanced equation.

1 mark: the molar mass and the amount of carbonate.

1 mark: the mass of calcium oxide, with its unit.

QUESTION 27 · MASS LOSS AS A COMPLETION CHECK · 2 MARKS

mass lost = 250.0 − 140.1 = 109.9 g

percentage lost = 109.9 / 250.0 × 100 = 43.97 per cent

Why the plant uses it. Complete decomposition of pure calcite must lose exactly 43.97 per cent of the charge mass, because that ratio is fixed by the formula and nothing else. Weighing the charge in and the product out gives a loss figure that can be compared with 43.97 per cent directly. A smaller loss means the roast is incomplete or the charge was not pure calcite; a larger loss means something else has decomposed or material has been carried out with the gas.

Marks

1 mark: the percentage of the charge lost, computed correctly.

1 mark: the reason tied to the fixed formula ratio, not a general statement about checking results.

QUESTION 28 · LIMITING REAGENT AND EXCESS BARIUM · 3 MARKS

Definition. The limiting reagent is the reactant that is entirely consumed first, so it sets the maximum amount of product that the reaction can form. Every other reactant is in excess and some of it remains unreacted.

Why barium chloride is added in excess. The laboratory wants every sulfate ion in the sample to be precipitated, because the mass of barium sulfate collected is being used to measure how much sulfate was there. Adding barium in excess forces the sulfate to be the limiting reagent, so the precipitate represents all of it. If barium were limiting, some sulfate would stay in solution and the reported concentration would be too low.

QUESTION 29 · CONCORDANT TITRES · 3 MARKS

The concordant titres are 21.30, 21.40 and 21.35 mL. They agree within 0.10 mL of one another. The 22.85 mL titre is the rough titre: it sits 1.5 mL above the others and is excluded because a rough titre is run quickly to locate the endpoint and routinely overshoots it.

mean titre = (21.30 + 21.40 + 21.35) / 3 = 21.35 mL

Marks

1 mark: identifies the three concordant titres.

1 mark: the correct mean of those three only.

1 mark: the justification for excluding the rough titre, naming what a rough titre is for rather than saying only that it looks different.

QUESTION 30 · CONCENTRATION OF THE PLANT ACID · 4 MARKS

H_2SO_4 (aq) + 2NaOH (aq) $\rightarrow$ Na_2SO_4 (aq) + $2H_2O$ (l)

n(NaOH) = c × V = 0.100 × 0.02500 = 2.50×10^{-3} mol

From the equation, 1 mol of acid neutralises 2 mol of base.

$n(H_2SO_4) = 2.50 \times 10^{-3} / 2 = 1.25 \times 10^{-3}$ mol

$c(H_2SO_4)$ = n / V = 1.25×10^{-3} / 0.02135 = 0.0585 mol/L

The mark most candidates drop

The factor of two. A monoprotic habit is easy to fall into, and the equation is on the page precisely so that you use the ratio it states. Writing the ratio out in words before you substitute costs four seconds and protects two marks.

QUESTION 31 · SIGNIFICANT FIGURES IN A REPORTED RESULT · 3 MARKS

The judgement. The reported value 0.058546 mol/L is not defensible. A calculated result carries no more significant figures than the least precise measurement it was built from. The concentration used was quoted to three significant figures, so the answer is justified to three: 0.0585 mol/L.

What the extra digits claim. Five significant figures claims the concentration is known to about one part in a hundred thousand. No volumetric glassware in a school or plant laboratory supports that. Reporting them is a claim about precision that the apparatus cannot back.

The rule to apply. Carry full precision through every intermediate step and round only at the final answer. Rounding at each step introduces an error of its own, and rounding at none at all makes a claim you cannot support.

QUESTION 32 · ZINC IN THE PLANT ACID, EQUATIONS · 3 MARKS

$Zn\ (s) + H_2SO_4\ (aq) \rightarrow ZnSO_4\ (aq) + H_2\ (g)$

Oxidation: $Zn \rightarrow Zn^{2+} + 2e^-$

Reduction: $2H^+ + 2e^- \rightarrow H_2$

Check the electrons. Two electrons are released by the zinc and two are taken up by the hydrogen ions, so the half equations combine without any multiplying factor. Saying so protects the mark on a question where they do not.

QUESTION 33 · THE LIMITING REAGENT · 2 MARKS

$n(Zn) = 3.27 / 65.38 = 0.0500$ mol

$n(H_2SO_4) = 0.100 \times 0.4000 = 0.0400$ mol

The ratio is 1 to 1, so 0.0500 mol of zinc would need 0.0500 mol of acid and only 0.0400 mol is available. The sulfuric acid is the limiting reagent and 0.0100 mol of zinc, which is 0.654 g, remains unreacted.

Marks

1 mark: both amounts computed correctly.

1 mark: the comparison made against the mole ratio, with the limiting reagent named. Naming it without the comparison is an assertion, not an answer.

QUESTION 34 · VOLUME OF HYDROGEN · 2 MARKS

$n(H_2) = n(H_2SO_4) = 0.0400$ mol

$V = n \times Vm = 0.0400 \times 24.79 = 0.992$ L

Where candidates lose this question

By computing the hydrogen from the zinc. The whole point of question 33 is that the zinc is in excess, so the zinc figure is the wrong one to carry forward. Circle the limiting reagent on your own paper the moment you identify it.

QUESTION 35 · MAGNESIUM IN COPPER(II) SULFATE · 4 MARKS

Ionic equation: $Mg\ (s) + Cu^{2+}\ (aq) \rightarrow Mg^{2+}\ (aq) + Cu\ (s)$

Oxidised. Magnesium. It loses two electrons and its oxidation number rises from 0 to +2.

Reduced. The copper(II) ion. It gains two electrons and its oxidation number falls from +2 to 0, which is the brown solid deposited on the ribbon.

How the activity series predicts it. Magnesium sits above copper in the activity series, so magnesium loses electrons more readily than copper does. A metal displaces from solution any metal ion below it in the series, so magnesium displaces copper and the reverse reaction does not occur.

QUESTION 36 · DISTINGUISHING A CARBONATE FROM A SULFATE · 4 MARKS

Test 1, dilute acid. Add dilute hydrochloric acid to a small portion of the solid. A carbonate effervesces, releasing carbon dioxide, which turns limewater milky. A sulfate gives no effervescence.

$CaCO_3\ (s) + 2HCl\ (aq) \rightarrow CaCl_2\ (aq) + H_2O\ (l) + CO_2\ (g)$

Test 2, acidified barium chloride. Dissolve a portion, acidify with dilute hydrochloric acid, then add barium chloride solution. A sulfate gives a white precipitate of barium sulfate that does not dissolve in the acid. A carbonate gives no precipitate, because any barium carbonate that might form is dissolved by the acid already present.

Why the acidification matters. Without it, a carbonate would also give a white precipitate and the test would not distinguish the two ions at all. The acid is what makes the test valid.

QUESTION 37 · GRAVIMETRIC SULFATE ON THE RETURN LINE · 4 MARKS

$M(BaSO_4) = 137.3 + 32.07 + 4(16.00) = 233.37$ g/mol

$n(BaSO_4) = 0.4382 / 233.37 = 1.878 \times 10^{-3}$ mol

Each mole of precipitate contains one mole of sulfate, so $n(SO_4^{2-}) = 1.878 \times 10^{-3}$ mol.

$M(SO_4) = 32.07 + 4(16.00) = 96.07$ g/mol

$m(\text{sulfate}) = 1.878 \times 10^{-3} \times 96.07 = 0.1804$ g

concentration = 0.1804 / 0.1750 = 1.031 g/L, which is 1031 mg/L

Why the sample is acidified. Acid dissolves carbonate, which would otherwise precipitate as barium carbonate and be weighed as though it were sulfate. Acidifying makes the measurement specific to sulfate, so it is a validity measure rather than an accuracy one.

The plant reading. The standing figure for the licence return line is 1009 mg/L. This sample at 1031 mg/L is about 2 per cent above it, which is within the run to run variation of a gravimetric determination rather than evidence of a change in the process.

QUESTION 38 · ENTHALPY AGAINST ENTROPY · 4 MARKS

Enthalpy change. The net heat energy absorbed or released by a reaction at constant pressure. It is negative when the energy released in forming bonds exceeds the energy absorbed in breaking them, and positive when the reverse holds.

Entropy change. The change in the dispersal of energy and matter among the particles. It is positive when the products are more disordered than the reactants, most commonly when the number of moles of gas increases.

What each contributes. A reaction is spontaneous when the free energy change is negative. A negative enthalpy change pushes towards spontaneity and a positive entropy change does the same, with the entropy term weighted by the absolute temperature. When the two terms oppose one another, temperature decides which of them wins.

QUESTION 39 · CALORIMETRY WITH THE SPIRIT BURNER · 5 MARKS

$C_2H_6O\ (l) + 3O_2\ (g) \rightarrow 2CO_2\ (g) + 3H_2O\ (l)$

$q = m\ c\ \Delta T = 150.0 \times 4.18 \times 11.4 = 7148$ J, or 7.148 kJ

Note the mass used. It is the mass of the water, not the mass of the fuel. The fuel supplies the energy and the water measures it. This is the single most common error in the topic.

$M(C_2H_6O) = 2(12.01) + 6(1.008) + 16.00 = 46.07$ g/mol

$n(\text{ethanol}) = 0.412 / 46.07 = 8.943 \times 10^{-3}$ mol

$\Delta H = q / n = 7.148 / (8.943 \times 10^{-3}) = 799$ kJ/mol released, so ΔH is negative 799 kJ/mol.

Marks

1 mark: the balanced combustion equation.

1 mark: q computed from the mass of the water.

1 mark: the molar mass and the amount of fuel.

2 marks: the molar enthalpy, with the sign stated and justified from the observed temperature rise rather than attached by rote.

QUESTION 40 · ACCOUNTING FOR THE DIFFERENCE · 3 MARKS

The experiment recovered 799.3 kJ/mol against an accepted 1367 kJ/mol, which is 58.5 per cent of it. The measured value is too low, and every significant error acts in that direction:

- Heat is lost to the air and to the can rather than entering the water, so the temperature rise understates the energy released and the result is too low.
- Combustion in an open burner is incomplete, visible as soot on the can, so some carbon is not fully oxidised and less energy is released per mole burned, again making the result too low.
- Ethanol evaporates from the wick between weighings, so the mass recorded as burned is larger than the mass actually combusted, which divides the same heat by a larger amount and makes the result too low.

The conclusion that earns the last mark. All three act in the same direction, so the error is systematic rather than random. Repeating the experiment would improve the precision and would not move the mean any closer to the accepted value. Only insulating the calorimeter, enclosing the flame and weighing immediately would do that.

QUESTION 41 · MARKING CRITERIA AND EXEMPLAR

MARKS	CRITERIA
7 to 8	Names galvanic corrosion and states all three requirements: two metals of different reactivity, electrical contact and an electrolyte. Uses the activity series to justify which metal is the anode rather than asserting it. Writes both half equations correctly, balances the electrons and gives a correct overall equation. Gives each control measure a mechanism and a named weakness, and reaches an explicit judgement justified by comparing how each measure fails.
5 to 6	Explains galvanic corrosion with most requirements named. Both half equations present and substantially correct, though the electrons may not be balanced before combining. Both measures described with a mechanism. A judgement is reached but is justified on cost or effectiveness alone rather than on failure mode.
3 to 4	Identifies that a cell forms and that the iron corrodes, but the reasoning is asserted rather than tied to the activity series. One half equation correct, or both present with errors. Both measures named but only one given a mechanism. No judgement.
1 to 2	States that the iron rusts and that zinc or paint would help. Little or no use of half equations. Relevant vocabulary appears without being connected into an explanation.

EXEMPLAR RESPONSE, QUESTION 41

Iron and copper are two metals of different reactivity, they are in electrical contact through the bolts, and the river water is an electrolyte because it carries dissolved ions. Those three conditions together make a galvanic cell, so this is galvanic corrosion and it is faster than the corrosion iron would suffer alone.

Iron sits above copper in the activity series, so iron loses electrons more readily. Iron therefore becomes the anode and is oxidised while the copper is the cathode and is protected.

At the anode: $Fe\ (s) \rightarrow Fe^{2+}\ (aq) + 2e^-$

At the cathode: $O_2\ (g) + 2H_2O\ (l) + 4e^- \rightarrow 4OH^-\ (aq)$

Balancing the electrons two to one gives the overall reaction:

$2Fe\ (s) + O_2\ (g) + 2H_2O\ (l) \rightarrow 2Fe^{2+}\ (aq) + 4OH^-\ (aq)$

Measure 1, a sacrificial anode. Bolt blocks of zinc to the piles. Zinc is above iron in the activity series, so zinc becomes the anode and is oxidised instead: $Zn \rightarrow Zn^{2+} + 2e^-$. The iron is forced to be the cathode and stops dissolving. Its weakness is that it is consumed, so it works only while zinc remains and has to be inspected and replaced.

Measure 2, a barrier coating. Paint the piles, or coat them in a polymer, to exclude oxygen and water. It is cheaper and immediately effective. Its weakness is that it fails at any scratch, and a small break concentrates the whole corrosion current into a small area, so the metal is pierced faster at that point than an uncoated pile would corrode overall.

Judgement. For a permanently immersed structure that is difficult to inspect, the sacrificial anode is the better single control, because its failure mode is gradual and predictable while a coating's is sudden and concentrated. The strongest practice is both together: the coating reduces the total exposed area and the anode protects wherever the coating has failed.

> Assess means reach a judgement and support it. A response that lists two options and stops has answered describe, and describe is not the verb on the page.

QUESTION 42 · MARKING CRITERIA AND EXEMPLAR

MARKS	CRITERIA
6 to 7	Calculates the percentage of calcite correctly through the amount of carbon dioxide lost, with the balanced equation quoted and the mole ratio stated. Uses the computed figure, not a general statement, to argue that the carbonate fraction is large enough to matter. Explains the reactivity of the carbonate with acid and connects both the number and the reactivity to the leaching decision, reaching a justified conclusion.

MARKS	CRITERIA
4 to 5	Calculates the percentage correctly or with one minor arithmetic slip. Explains the reactivity of carbonate with acid. The link to the leaching decision is made but rests on only one of the two strands, usually the reactivity, with the number left unused.
2 to 3	Some correct stoichiometry, for example the amount of carbon dioxide, without reaching a percentage. Or a correct percentage with no attempt to connect it to the process. Relevant vocabulary present.
	1 mark: one relevant statement, such as that the mass loss is carbon dioxide, with no development.

EXEMPLAR RESPONSE, QUESTION 42

The mass lost is carbon dioxide, released as the carbonate decomposes:

$CaCO_3$ (s) + 2HCl (aq) $\rightarrow$ $CaCl_2$ (aq) + H_2O (l) + CO_2 (g)

$M(CO_2) = 12.01 + 2(16.00) = 44.01$ g/mol

$n(CO_2) = 0.4136 / 44.01 = 9.398 \times 10^{-3}$ mol

The ratio of calcite to carbon dioxide is 1 to 1, so $n(CaCO_3) = 9.398 \times 10^{-3}$ mol.

$m(CaCO_3) = 9.398 \times 10^{-3} \times 100.09 = 0.9406$ g

percentage calcite = 0.9406 / 2.500 × 100 = 37.6 per cent

What the number means for the process. Over a third of the ore by mass is calcite, and calcite carries no copper at all. Feeding it to the roaster means heating 37.6 per cent of every tonne to roasting temperature for no product, and the carbonate decomposes there as well, so the fuel is spent driving off carbon dioxide from a mineral that was never wanted.

What the reactivity contributes. Calcite reacts readily with dilute acid at ambient temperature, dissolving as calcium chloride and releasing carbon dioxide, while chalcocite does not dissolve in dilute acid. The two minerals differ sharply in their reactivity with acid, which is what makes a separation by acid leaching possible at all.

Conclusion. Leaching first is justified on both grounds together. The quantitative result says the carbonate fraction is large enough that removing it materially raises the grade of the roaster feed, and the reactivity result says it can be removed cheaply and selectively with dilute acid. Either fact alone would be insufficient: a small carbonate fraction would not repay the extra stage, and a carbonate that did not react selectively could not be removed this way.

Track this paper across the term

Sit this paper three times, at least three weeks apart, and date each attempt.

Record your Section I and Section II totals separately. They fail for different reasons and they are fixed by different work.

> Three hours once is worth more than nine hours spread across a week. The clock is part of the skill.

Practice Paper 4, tracked

Date each attempt, record the section marks separately, and name one change. Section I and Section II fail for different reasons. A single total out of 100 hides which one is costing you. Make one change per paper.

DATE	SECTION I AND SECTION II MARKS	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), Modules 1 to 4, for students sitting the HSC in 2028. A new Chemistry syllabus is first examined in HSC 2029. The paper matches the HSC specification in marks, section split and item count.
Every question 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 worked solution was recomputed from its inputs before printing.

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