MA99 EDUCATION

Chemistry: Practice Paper 1

1

NSW CHEMISTRY STAGE 6 SYLLABUS 2017

FOR HSC 2027 AND 2028

1. Instructions

General instructions

- Reading time, 5 minutes. Working time, 3 hours. Total marks, 100.
- Write using black pen.
- A data sheet, a formulae sheet and a Periodic Table are provided.
- Approved calculators may be used.
- Section I, 20 marks. Attempt Questions 1 to 20. Allow about 35 minutes.
- Section II, 80 marks. Attempt Questions 21 onwards. Allow about 2 hours and 25 minutes.
- Show all relevant working in questions involving calculations.

This paper is built to the HSC specification. The marks, the section split and the item count all match it, so a mark out of 100 here is worth comparing with a mark out of 100 in a trial.

MODULE	SECTION I	SECTION II	SHARE
Module 5 · Equilibrium and Acid Reactions	5 marks	16 marks	21 per cent
Module 6 · Acid/base Reactions	5 marks	16 marks	21 per cent
Module 7 · Organic Chemistry	5 marks	17 marks	22 per cent
Module 8 · Applying Chemical Ideas	5 marks	16 marks	21 per cent
Extended response section, Questions 40 and 41, drawing on several modules	none	15 marks	15 per cent

Timing. Section I is 20 marks in about 35 minutes, which is under two minutes a question. Section II is 80 marks in about 145 minutes, which is a little under two minutes a mark across twenty one items. If a question is taking more than double its mark value in minutes, leave a gap and come back. Students lose more marks to unfinished questions at the end than to wrong ones in the middle.

Sit it in one go. Three hours, one sitting, no notes and no phone. A paper attempted in three separate half hours tells you what you know. A paper attempted in one three hour block tells you what you can produce, and the gap between those two numbers is where most of a cohort's lost marks sit.

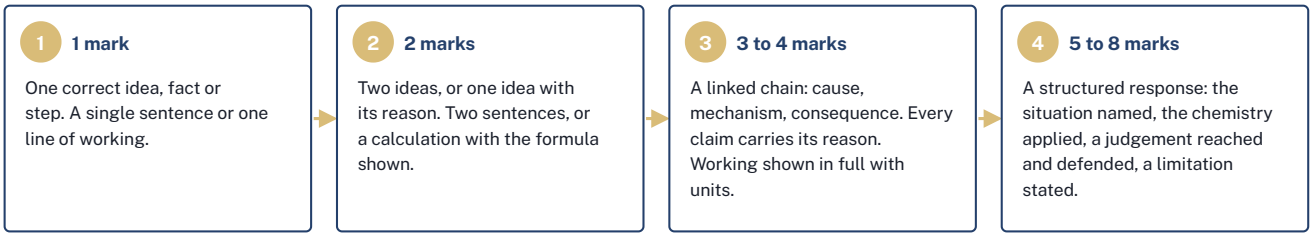


Figure 1 · What each mark value is asking you to produce. Check your answer length against this before you write.

> The question is not asking you to write everything you know. It is asking you for the number of ideas printed next to it.

2. Section I · Multiple choice

20 marks. Attempt Questions 1 to 20. Allow about 35 minutes.

Use the grid below to record your answers, then transfer them. One mark each, no working required and no penalty for a wrong answer, so leave nothing blank.

2.1 Section I answer grid

Write the letter, not a tick. Transfer them in one pass at the end, and check the numbering as you go. A question skipped on the paper and not skipped on the grid costs every answer after it.

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

Module 5 · Equilibrium and Acid Reactions

Question 1

1 MARK

The calciner at the Kerrindal Works roasts calcite in a closed vessel: $CaCO_3$ (s) ⇌ CaO (s) + CO_2 (g), which absorbs energy. Which statement is correct?

A The forward reaction is favoured by raising the temperature, because it is endothermic

B The forward reaction is favoured by raising the pressure, because gas is produced

C Adding more calcite shifts the equilibrium to the right

D Removing carbon dioxide has no effect because it is a gas

Question 2

1 MARK

For the equilibrium $2SO_2$ (g) + O_2 (g) ⇌ $2SO_3$ (g), the correct expression for the equilibrium constant is

A $[SO_3] / ([SO_2][O_2])$

B $[SO_3]^2 / ([SO_2]^2[O_2])$

C $([SO_2]^2[O_2]) / [SO_3]^2$

D $2[SO_3] / (2[SO_2] + [O_2])$

Question 3

1 MARK

A reaction at equilibrium has Keq = 4.8×10^{-7} at 25 degrees Celsius. This tells you that at equilibrium

A the reaction is very fast

B the reaction is very slow

C the mixture is almost entirely reactants

D the mixture is almost entirely products

Question 4

1 MARK

A saturated solution of lead(II) iodide is in contact with undissolved solid. Potassium iodide solution is added. The immediate result is that

A more lead(II) iodide dissolves, because the solution is disturbed

B additional lead(II) iodide precipitates, because the iodide ion concentration has risen

C the solubility product Ksp increases

D the lead ion concentration is unchanged, because Ksp is a constant

Question 5

1 MARK

Which change would increase the yield of sulfur trioxide in the contact process, $2SO_2 + O_2 \rightleftharpoons 2SO_3$, which releases energy?

A Raising the temperature
B Lowering the total pressure
C Adding a catalyst
D Raising the total pressure

Module 6 · Acid/base Reactions

Question 6

1 MARK

According to the Brønsted-Lowry model, in the reaction $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$, water acts as

A an acid, because it donates a proton
B a base, because it accepts a proton
C an acid, because it accepts a proton
D neither, because it is the solvent

Question 7

1 MARK

Which pair is a conjugate acid and base pair?

A H_2SO_4 and SO_4^{2-}
B CH_3COOH and CH_3COO^-
C H_3O^+ and OH^-
D NH_4^+ and NH_2^-

Question 8

1 MARK

Equal volumes of 0.100 mol/L hydrochloric acid and 0.100 mol/L ethanoic acid are each titrated against 0.100 mol/L sodium hydroxide. Compared with the hydrochloric acid, the ethanoic acid requires

A a smaller volume of base and has a lower initial pH
B the same volume of base and has a higher initial pH
C a larger volume of base and has a higher initial pH
D the same volume of base and has a lower initial pH

Question 9

1 MARK

The licence condition KR 14 requires the Kerrindal River to stay between pH 6.5 and pH 8.5. A return line sample reads pH 5.5. Compared with a sample at pH 8.5, the hydronium ion concentration in the failing sample is

A 3 times greater
B 300 times greater
C 1000 times greater
D 3000 times greater

Question 10

1 MARK

Which indicator is the best choice for the titration of ethanoic acid with sodium hydroxide?

A Methyl orange, which changes between pH 3.1 and 4.4
B Bromothymol blue, which changes between pH 6.0 and 7.6
C Phenolphthalein, which changes between pH 8.3 and 10.0
D Any of them, because the equivalence point is always at pH 7

Module 7 · Organic Chemistry

Question 11

1 MARK

Which compound is a structural isomer of butan-1-ol?

A Butanal
B Butanoic acid
C Butan-2-ol
D Pentan-1-ol

Question 12

1 MARK

The systematic name of CH_3CH_2COOH is

A Ethanoic acid
B Propanoic acid
C Propanal
D Propan-1-ol

Question 13

1 MARK

Ethanol and ethanoic acid are heated under reflux with a few drops of concentrated sulfuric acid. The organic product is

A Ethyl ethanoate
B Ethyl ethanoic acid
C Diethyl ether
D Ethene

Question 14

1 MARK

Propan-1-ol boils at 97 degrees Celsius and butane boils at negative 1 degree Celsius, although the two molecules have similar molar masses. The reason is that propan-1-ol molecules

A have stronger covalent bonds
B are held together by hydrogen bonding because of the bonded hydroxyl group
C are ionic in the liquid state
D are larger and therefore have stronger dispersion forces

Question 15

1 MARK

Low density polyethene lines the Kerrindal recovery tank and high density polyethene is used for the pipework. Compared with the low density form, the high density form has

A shorter chains and a lower melting point
B less chain branching, so the chains pack more closely and the material is more rigid
C more chain branching, so the chains pack more closely
D a different monomer and a different repeating unit

Module 8 · Applying Chemical Ideas

Question 16

1 MARK

A flame test on a Kerrindal water sample gives a persistent yellow colour. This indicates the presence of

A Potassium ions
B Sodium ions
C Calcium ions
D Copper(II) ions

Question 17

1 MARK

Atomic absorption spectroscopy is preferred over a gravimetric method for lead in river water mainly because

A it is cheaper to install
B it identifies the oxidation state of the lead
C it measures concentrations far below the level a precipitate could be weighed at
D it requires no calibration

Question 18

1 MARK

In a proton nuclear magnetic resonance spectrum, the number of peaks tells you

A the number of carbon atoms in the molecule
B the number of chemically different hydrogen environments
C the molar mass of the compound
D the number of hydrogen atoms in the molecule

Question 19

1 MARK

An infrared spectrum of an unknown Kerrindal solvent shows a broad strong absorption near 3300 reciprocal centimetres and no absorption near 1700 reciprocal centimetres. The compound most likely contains

A a carboxyl group

B a hydroxyl group

C a carbonyl group only

D a carbon to carbon double bond only

Question 20

1 MARK

A sulfate determination is carried out by precipitating barium sulfate, then filtering, drying and weighing it. The precipitate is washed before drying mainly to

A dissolve any excess barium sulfate

B remove soluble ions that would otherwise be weighed with the precipitate

C speed up the drying

D convert the precipitate to the anhydrous form

> Two minutes a question in Section I. A question you cannot start in thirty seconds is a question to mark and come back to.

3. Section II · Short answer, calculation and extended response

80 marks. Attempt Questions 21 to 41. Allow about 2 hours and 25 minutes.

Answer in the spaces provided. Show all relevant working in questions involving calculations. Where a question asks you to explain, a statement of fact is not an explanation: the mark sits in the sentence that says why.

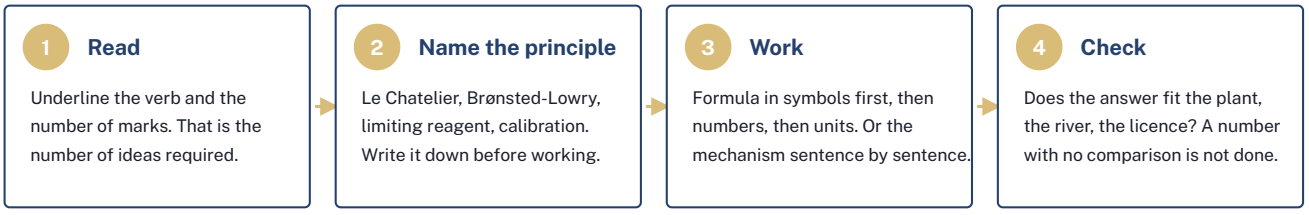


Figure 2 · The same four moves on every Section II item. Read, name the principle, work, then check the answer against the context.

Module 5 · Equilibrium and Acid Reactions

Question 21

4 MARKS

The Kerrindal sulfuric acid plant runs the contact process. At 500 degrees Celsius a sealed vessel reaches equilibrium with $[SO_2]$ = 0.0450 mol/L, $[O_2]$ = 0.0320 mol/L and $[SO_3]$ = 0.184 mol/L.

(a) Write the balanced equation and the expression for Keq. 1 MARK

(b) Calculate the value of Keq at this temperature. **3 MARKS**

Question 22

4 MARKS

The calciner roasts calcite: $CaCO_3$ (s) $\rightleftharpoons$ CaO (s) + CO_2 (g). The reaction absorbs energy.

(a) Explain the effect on the equilibrium yield of carbon dioxide of raising the operating temperature. **2 MARKS**

(b) The plant engineer proposes adding more calcite to raise the yield of carbon dioxide. Explain whether this will work. **2 MARKS**

Question 23

3 MARKS

A saturated solution of lead(II) iodide sits above undissolved solid in a settling tank. Explain what is happening at the particle level, and explain why the measured lead concentration stays constant while both processes continue.

Question 24

2 MARKS

Keq for a gas phase reaction is 0.0043 at 300 degrees Celsius and 0.190 at 600 degrees Celsius. Deduce whether the forward reaction releases or absorbs energy, and justify your answer.

Question 25

3 MARKS

Explain why adding a catalyst to the contact process increases the rate at which equilibrium is reached but does not change the equilibrium yield of sulfur trioxide.

Module 6 · Acid/base Reactions

Question 26

4 MARKS

The plant standard acid is 0.100 mol/L sulfuric acid, which for this question ionises completely in both steps.

(a) Calculate the pH of the standard acid. **1 MARK**

(b) A 25.0 mL portion is diluted to 500.0 mL. Calculate the pH of the diluted solution. **3 MARKS**

Question 27

4 MARKS

The assay laboratory titrates 25.00 mL portions of a return line sample against 0.100 mol/L sodium hydroxide. The acid present is sulfuric acid. Three concordant titres average 21.85 mL.

(a) Write the balanced equation for the titration reaction. **1 MARK**

(b) Calculate the concentration of sulfuric acid in the sample. **3 MARKS**

Question 28

3 MARKS

Ethanoic acid has Ka = 1.74×10^{-5} at 25 degrees Celsius.

(a) Write the equation for the ionisation of ethanoic acid in water. **1 MARK**

(b) Calculate the pH of a 0.100 mol/L solution, stating one assumption. **2 MARKS**

Question 29

3 MARKS

Explain why 0.100 mol/L ethanoic acid and 0.100 mol/L hydrochloric acid require the same volume of 0.100 mol/L sodium hydroxide to reach the equivalence point, although their initial pH values differ by about two units.

Question 30

2 MARKS

A student rinses the burette with distilled water and fills it with standard base without rinsing it with the base first. Explain the effect on the calculated acid concentration.

Module 7 · Organic Chemistry

Question 31

5 MARKS

The Kerrindal solvent plant makes ethyl ethanoate by heating ethanoic acid with ethanol under reflux with a concentrated sulfuric acid catalyst, then distilling the product out. A standing batch charges 92.0 g of ethanol against 150.0 g of ethanoic acid and recovers 105.0 g of ester.

(a) Write the balanced equation for the esterification. **1 MARK**

(b) Show by calculation that ethanol is the limiting reagent. **2 MARKS**

(c) Calculate the percentage yield of the batch. **2 MARKS**

Question 32

4 MARKS

Explain why the esterification mixture is heated under reflux rather than in an open flask, and explain why the ester is then distilled out of the mixture.

Question 33

4 MARKS

Explain why propan-1-ol boils at 97 degrees Celsius while butane, of similar molar mass, boils at negative 1 degree Celsius. Name the intermolecular forces present in each and state which forces are overcome during boiling.

Question 34

4 MARKS

The recovery tank is lined with low density polyethene and the pipework is high density polyethene.

(a) Name the monomer and write the equation for the addition polymerisation, using n for the number of monomer units.

2 MARKS

(b) Explain, in terms of chain branching and packing, why the pipework uses the high density form. **2 MARKS**

Module 8 · Applying Chemical Ideas

Question 35

4 MARKS

Lead in the Kerrindal River is measured by atomic absorption spectroscopy. Standards from 0.00 to 4.00 mg/L give a calibration line through the origin with a gradient of 0.0470 absorbance units per mg/L. A river sample gives an absorbance of 1.120.

(a) Calculate the lead concentration in the sample. **2 MARKS**

(b) The sample reads above the highest standard. Explain what the analyst should do before reporting the result. **2 MARKS**

Question 36

4 MARKS

An unknown organic compound has the molecular formula $C_3H_6O_2$. Its infrared spectrum shows a broad absorption from 2500 to 3300 reciprocal centimetres and a strong absorption near 1710 reciprocal centimetres. Its proton nuclear magnetic resonance spectrum shows three peaks in the ratio 3 to 2 to 1. Deduce the structure and justify each piece of evidence you use.

Question 37

4 MARKS

The assay laboratory must confirm that a white solid is a sulfate and not a carbonate. Describe a test, state the expected observation for each possibility, and write a balanced equation for the positive result.

Question 38

2 MARKS

Explain why atomic absorption spectroscopy is preferred over a gravimetric method for measuring lead at the concentrations found in river water.

Question 39

2 MARKS

River sediment at the old cell house outfall assays 11.44 per cent lead by mass while the water above it reads 23.8 mg/L. Explain what this comparison tells an investigator about where the contamination is held.

Extended response

Question 40

8 MARKS

The Kerrindal Works must keep the river between pH 6.5 and pH 8.5 under licence condition KR 14. The return line currently runs at pH 5.5 because of dissolved sulfuric acid. Assess the use of a titration based monitoring programme, supported by a neutralisation dosing system, as the plant's method of meeting the condition. Include a relevant balanced equation, explain how the monitoring data would be used, and identify one limitation.

Question 41

7 MARKS

A drum of unlabelled organic liquid is found in the solvent plant store. It is known to be one of ethanol, ethanoic acid or ethyl ethanoate. Design a sequence of tests, using both chemical tests and one instrumental technique, that would identify the liquid with certainty. Justify the order of your tests and state what each result would rule out.

4. Solutions

Every answer, with the reasoning a marker is looking for.

Mark your own paper before you read a single solution. Reading solutions cold teaches you what a good answer looks like. Reading them after your own attempt teaches you what you personally do instead, which is the only thing you can change.

Section I · Answers and reasoning

Q	ANSWER	MODULE	WHY, AND WHAT THE DISTRACTORS WERE TESTING
1	A	M5	The reaction absorbs energy, so heating shifts it towards the products by Le Chatelier. B is wrong because raising the pressure on a system that produces gas shifts it back. C is the common trap: adding more of a pure solid does not change its concentration term. D is simply false.
2	B	M5	Products over reactants, each raised to its coefficient. A forgets the squares. C is the reciprocal, which is the expression for the reverse reaction. D multiplies coefficients rather than using them as powers.
3	C	M5	A very small Keq means the numerator, the products, is tiny compared with the denominator. A and B are the standard confusion: the equilibrium constant says nothing at all about rate.
4	B	M5	Added iodide raises the ion product above Ksp, so solid forms until the product falls back. C is wrong because Ksp is fixed at a given temperature. D misses that the lead concentration must fall as iodide rises.
5	D	M5	Three moles of gas become two, so raising the pressure shifts the system towards fewer gas molecules. A lowers the yield because the reaction releases energy. C changes only the rate.
6	A	M6	Water gives a proton to ammonia, so water is the acid here. B reverses the roles. C contradicts itself. D is the idea that a solvent cannot react, which is wrong.
7	B	M6	A conjugate pair differs by exactly one proton. A differs by two. C differs by two. D differs by two.
8	B	M6	Concentration and the number of acidic protons set the titre, not strength, so the volumes match. The weak acid is only partly ionised, so its initial pH is higher. A and C are the classic error of confusing strength with concentration.
9	C	M6	Three pH units is a factor of ten cubed, which is one thousand. A treats pH as linear, which is the single most common error in this topic.
10	C	M6	A weak acid against a strong base has its equivalence point above pH 7, because the conjugate base hydrolyses. Phenolphthalein is the only indicator listed whose range covers it. D is the belief that equivalence always means neutral.
11	C	M7	Butan-2-ol has the same molecular formula as butan-1-ol with the hydroxyl group on a different carbon. A and B are different functional groups. D has an extra carbon.
12	B	M7	Three carbons and a carboxyl group gives propanoic acid. A has two carbons, C is the aldehyde, D is the alcohol.
13	A	M7	Acid plus alcohol under acid catalysis gives an ester and water. B is not a compound. C requires different conditions. D would need dehydration of the alcohol at a much higher temperature.
14	B	M7	The bonded hydroxyl hydrogen permits hydrogen bonding, which is far stronger than the dispersion forces in butane. A confuses bonds with intermolecular forces. D is false because the molar masses are similar.
15	B	M7	Less branching means closer packing, stronger total dispersion forces and a more rigid, higher melting material. C reverses the logic. D is wrong: both forms are made from ethene.
16	B	M8	Sodium gives a persistent yellow flame. Potassium is lilac, calcium is brick red and copper(II) is blue green.
17	C	M8	Atomic absorption works at parts per billion, far below the mass a balance could resolve as a precipitate. B is false: it detects the element, not its oxidation state. D is false, calibration is essential.
18	B	M8	Peak count gives the number of chemically distinct hydrogen environments. The area under the peaks gives the ratio of hydrogen numbers, which is how D becomes the attractive wrong answer.

Q	ANSWER	MODULE	WHY, AND WHAT THE DISTRACTORS WERE TESTING
19	B	M8	A broad band near 3300 with no carbonyl band points to an alcohol. A carboxyl group would show both a broad band and a strong carbonyl absorption near 1710, which is how A is eliminated.
20	B	M8	Washing removes soluble ions trapped in the precipitate, which would otherwise be dried and weighed as if they were barium sulfate and inflate the result. A would defeat the purpose of the determination.

> Every distractor in a well written multiple choice question reflects a common error in working. Identify which error it reflects.

Section II · Worked solutions

QUESTION 21 · THE CONTACT PROCESS EQUILIBRIUM · 4 MARKS

(a) $2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$

$K_{eq} = [SO_3]^2 / ([SO_2]^2\,[O_2])$

(b) $K_{eq} = (0.184)^2 / ((0.0450)^2 \times 0.0320)$

$K_{eq} = 0.033856 / (0.002025 \times 0.0320) = 0.033856 / 0.0000648 = 522$

ANSWER $K_{eq} = 522$ at 500 degrees Celsius, reported without a unit. A value well above one tells you the equilibrium mixture is mostly sulfur trioxide, which is what the plant is built to achieve.

MARKING CRITERIA

MARKS	CRITERIA
4	Correct balanced equation and K_{eq} expression, correct substitution with the squares applied, and the correct value.
3	Correct expression and substitution with one arithmetic slip in the value.
2	Correct expression and a substitution that is set out but not completed.
1	Balanced equation or K_{eq} expression correct, nothing further.

QUESTION 22 · THE CALCINER · 4 MARKS

(a) The forward reaction absorbs energy. Raising the temperature adds energy to the system, and by Le Chatelier the equilibrium shifts in the direction that absorbs it. That is the forward direction, so the yield of carbon dioxide rises.

(b) It will not work. Calcite is a pure solid, and the concentration of a pure solid is fixed by its density, not by how much of it is present. It therefore does not appear in the equilibrium expression, and adding more of it does not shift the position of equilibrium. What it does change is the length of time the kiln can run before the charge is exhausted, which is an operational matter, not an equilibrium one.

MARKING CRITERIA

MARKS	CRITERIA
4	Both effects correct with the reason given in each case, including the point that a pure solid has no concentration term.
3	Both answers correct with one reason incomplete.
2	One part fully correct with a reason.
1	A correct direction stated with no reason.

QUESTION 23 · THE SETTLING TANK · 3 MARKS

Solid lead(II) iodide is dissolving and dissolved ions are crystallising back onto the solid at the same time. At equilibrium the two rates are equal, so the number of ions entering solution each second equals the number leaving it.

Nothing has stopped. The concentration is constant because the two opposing processes are balanced, not because either has ceased. This is why the tank shows no visible change while the solid slowly recrystallises and rounds off over months.

MARKING CRITERIA

MARKS	CRITERIA
3	Names both opposing processes, states that the rates are equal, and explains that constant concentration follows from the balance rather than from cessation.
2	Both processes named and rates said to be equal, without the final link.
1	One process described, or equilibrium asserted without mechanism.

QUESTION 24 · DEDUCING THE ENERGY CHANGE · 2 MARKS

Keq rises from 0.0043 to 0.190 as the temperature rises, so the equilibrium has shifted towards the products. By Le Chatelier, heating shifts a system in the direction that absorbs energy. The forward reaction therefore absorbs energy, which means it is endothermic.

MARKING CRITERIA

MARKS	CRITERIA
2	Correct deduction with the reasoning tied to the rise in Keq and Le Chatelier.
1	Correct deduction with no reasoning, or correct reasoning with the wrong conclusion.

QUESTION 25 · THE CATALYST · 3 MARKS

A catalyst provides an alternative pathway of lower activation energy. A greater fraction of collisions therefore has enough energy to react, so both the forward and the reverse rate increase. Both rates increase by the same factor, so the point at which they become equal is unchanged. The catalyst changes how quickly the system arrives at equilibrium, not where equilibrium sits. Keq is unchanged, because Keq depends only on temperature.

MARKING CRITERIA

MARKS	CRITERIA
3	Explains the lower activation energy pathway, states that both rates rise equally, and concludes that the position of equilibrium and Keq are unchanged.
2	Two of those three ideas.
1	States the rate increases with no account of why the yield is unchanged.

QUESTION 26 · PH OF THE STANDARD ACID · 4 MARKS

(a) Sulfuric acid releases two protons per formula unit, so

$[H_3O^+] = 2 \times 0.100 = 0.200$ mol/L

pH = negative $\log_{10}(0.200) = 0.699$

(b) Dilution does not change the amount of acid, only the volume it occupies. $c_1V_1 = c_2V_2$, so $[H_3O^+] = 0.200 \times 25.0 / 500.0 = 0.0100$ mol/L

pH = negative $\log_{10}(0.0100) = 2.00$

ANSWER The standard acid is pH 0.699 and the diluted solution is pH 2.00. A twenty fold dilution raised the pH by 1.30 units, which is $\log_{10}$ of 20. That check takes five seconds and it catches a decimal place error.

MARKING CRITERIA

MARKS	CRITERIA
4	Both pH values correct, with the doubling for the second proton shown and the dilution handled by amount of substance.
3	One pH correct and the method for the other clearly correct.
2	Correct method with the second proton not accounted for.
1	A correct pH formula quoted with no correct value.

QUESTION 27 · TITRATING THE RETURN LINE · 4 MARKS

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

(b) n(NaOH) = c × V = 0.100 × 0.02185 = 2.185×10^{-3} mol

From the equation, one mole of sulfuric acid reacts with two moles of base, so

$n(H_2SO_4) = 2.185 \times 10^{-3} / 2 = 1.0925 \times 10^{-3}$ mol

$c(H_2SO_4)$ = n / V = 1.0925×10^{-3} / 0.02500 = 0.0437 mol/L

ANSWER The return line sample is 0.0437 mol/L in sulfuric acid.

MARKING CRITERIA

MARKS	CRITERIA
4	Balanced equation, correct moles of base, correct use of the one to two ratio and a correct concentration with units.
3	Correct method throughout with one arithmetic slip, or the ratio omitted but everything else correct.
2	Moles of base correct with no further correct progress.
1	Balanced equation only.

QUESTION 28 · PH OF A WEAK ACID · 3 MARKS

(a) CH_3COOH (aq) + H_2O (l) $\rightleftharpoons$ CH_3COO^- (aq) + H_3O^+ (aq)

(b) Ka = $[CH_3COO^-][H_3O^+] / [CH_3COOH]$

Assuming the acid ionises only slightly, so its equilibrium concentration is still about 0.100 mol/L, and that the two product concentrations are equal:

$[H_3O^+]$ = square root of (Ka × c) = square root of ($1.74 \times 10^{-5} \times 0.100$) = 1.32×10^{-3} mol/L

pH = negative $\log_{10}$ (1.32×10^{-3}) = 2.88

The assumption. That the amount ionised is negligible against the starting concentration. Here it is 1.3 per cent, which is comfortably inside the usual five per cent rule, so the assumption holds.

MARKING CRITERIA

MARKS	CRITERIA
3	Correct ionisation equation, correct hydronium concentration and pH, with the assumption stated.
2	Correct pH with no assumption stated, or correct method with an arithmetic slip.
1	Correct equation or correct Ka expression only.

QUESTION 29 · SAME TITRE, DIFFERENT PH · 3 MARKS

The equivalence point is set by the amount of acid present, not by how far the acid ionises. Both solutions contain 0.100 mol of acidic protons per litre, and both react with sodium hydroxide in a one to one ratio, so both require the same volume of base.

The initial pH differs because hydrochloric acid is fully ionised, giving $[H_3O^+]$ = 0.100 mol/L and pH 1.00, while ethanoic acid is only about 1.3 per cent ionised, giving pH 2.88.

The distinction the question is testing. Strength is the extent of ionisation. Concentration is the amount dissolved. The titre measures amount; the pH measures what has ionised. Confusing the two is the most heavily penalised error in Module 6.

MARKING CRITERIA

MARKS	CRITERIA
3	Explains that the titre depends on the amount of acid, explains the pH difference by extent of ionisation, and distinguishes strength from concentration.
2	Two of those three.
1	States that the volumes are the same or that the pH differs, with no explanation.

QUESTION 30 · THE UNRINSED BURETTE · 2 MARKS

The distilled water remaining in the burette dilutes the standard base, so the base delivered is less concentrated than 0.100 mol/L. A larger volume is then needed to reach the endpoint, so the titre is too large.

Because the calculation assumes the stated concentration, the extra volume is read as extra moles of base, and the acid concentration is reported too high. The error is systematic: it pushes every titre the same way.

MARKING CRITERIA

MARKS	CRITERIA
2	Identifies the dilution, states that the titre is too large, and concludes the reported acid concentration is too high.
1	Identifies the dilution without carrying it through to the reported result.

QUESTION 31 · THE ESTERIFICATION BATCH · 5 MARKS

(a) $CH_3COOH\ (l) + C_2H_5OH\ (l) \rightleftharpoons CH_3COOC_2H_5\ (l) + H_2O\ (l)$

(b) $M(C_2H_6O) = 2(12.01) + 6(1.008) + 16.00 = 46.07$ g/mol, so n(ethanol) = 92.0 / 46.07 = 2.00 mol. $M(CH_3COOH) = 2(12.01) + 4(1.008) + 2(16.00) = 60.05$ g/mol, so n(ethanoic acid) = 150.0 / 60.05 = 2.50 mol.

The reaction consumes the two in a one to one ratio. Ethanol supplies 2.00 mol against 2.50 mol of acid, so ethanol runs out first and is the limiting reagent.

(c) $M(C_4H_8O_2) = 4(12.01) + 8(1.008) + 2(16.00) = 88.10$ g/mol

Theoretical mass = (92.0 / 46.07) × 88.10 = 175.9 g

percentage yield = 105.0 / 175.9 × 100 = 59.7 per cent

ANSWER Ethanol is limiting, and the batch yields 59.7 per cent. The shortfall is not carelessness: esterification is an equilibrium, and the acid is charged in excess precisely to pull it further towards the ester.

MARKING CRITERIA

MARKS	CRITERIA
5	Balanced equation, both mole calculations correct, limiting reagent identified with the ratio quoted, theoretical mass and percentage yield both correct.
4	All of the above with one arithmetic slip carried through consistently.
3	Limiting reagent correctly identified with working, yield attempted.
2	Moles of both reactants correct, nothing further.
1	Balanced equation or one correct molar mass.

QUESTION 32 · REFLUX, THEN DISTILLATION · 4 MARKS

Why reflux. The mixture must be heated to give the reaction a workable rate, but ethanol boils at 78 degrees Celsius and the ester at 77 degrees Celsius. In an open flask both would evaporate away and be lost. Under reflux the vapour condenses on the cold condenser and returns to the flask, so the mixture can be held at its boiling point indefinitely with nothing escaping.

Why distil afterwards. Esterification is an equilibrium and does not go to completion, so the flask holds ester, water, unreacted acid and unreacted alcohol. Distilling the ester out as it forms leaves the ethanoic acid (boiling at 118 degrees Celsius) and most of the water behind. Because ethanol and the ester boil within about one degree of each other, a fractionating column is needed to separate them cleanly. Removing the ester also disturbs the equilibrium, which shifts further towards the products and raises the yield above what the equilibrium alone would give.

MARKING CRITERIA

MARKS	CRITERIA
4	Explains reflux as returning volatile material to the flask so the mixture can be heated without loss, and explains distillation as separating the ester and shifting the equilibrium.
3	Both purposes explained with one mechanism incomplete.
2	One purpose fully explained.

MARKS	CRITERIA
1	Names reflux or distillation without a mechanism.

QUESTION 33 · BOILING POINTS · 4 MARKS

Butane is a non-polar hydrocarbon. The only forces between its molecules are dispersion forces, which are weak.

Propan-1-ol carries a hydroxyl group, so its oxygen bears lone pairs and its bonded hydrogen is strongly polarised. Its molecules therefore form hydrogen bonds with one another, in addition to dispersion forces.

Boiling separates molecules from one another, so what must be overcome is the force between molecules, not the covalent bonds within them. Hydrogen bonding is far stronger than dispersion forces at this molecular size, so propan-1-ol needs much more energy to boil and its boiling point is about 98 degrees higher.

Worth writing once in every answer of this type. Boiling a molecular liquid breaks no covalent bonds at all.

MARKING CRITERIA

MARKS	CRITERIA
4	Names dispersion forces in butane and hydrogen bonding in propan-1-ol, explains why the hydroxyl group permits hydrogen bonding, and states that boiling overcomes intermolecular forces rather than covalent bonds.
3	Names both forces correctly and links them to the difference, without the final distinction.
2	Names both forces with limited linking.
1	States that propan-1-ol has stronger forces, unnamed.

QUESTION 34 · POLYETHENE · 4 MARKS

(a) The monomer is ethene, C_2H_4.

n $C_2H_4 \rightarrow (C_2H_4)n$, the addition polymerisation of ethene to polyethene.

(b) Low density polyethene has many short branches along its chains. The branches hold neighbouring chains apart, so the chains cannot approach closely, the total dispersion force between them is smaller, and the material is softer and more flexible with a lower melting point. High density polyethene has far less branching. Its chains pack closely and in places align into ordered regions, so the total dispersion force between chains is greater. The material is more rigid, stronger and higher melting, which is what pipework carrying solvent under pressure requires. The flexible low density form is the right choice for a tank liner, which must take the shape of the tank.

MARKING CRITERIA

MARKS	CRITERIA
4	Monomer named and the polymerisation equation written correctly, with branching, packing, dispersion forces and the resulting property difference all linked and applied to the pipework.
3	Equation correct and the branching argument made without the full link to properties.
2	Equation correct, or the branching argument correct, not both.
1	Monomer named only.

QUESTION 35 · THE LEAD CALIBRATION · 4 MARKS

(a) The calibration line passes through the origin, so absorbance = gradient × concentration.

c(Pb) = A / gradient = 1.120 / 0.0470 = 23.8 mg/L

(b) The highest standard was 4.00 mg/L and the sample reads 23.8 mg/L, which is far outside the calibrated range. The analyst cannot assume the response is still linear there, so the result is an extrapolation rather than a measurement.

The sample should be diluted by a known factor, typically ten fold, and re measured so that its absorbance falls within the range of the standards. The measured value is then multiplied by the dilution factor. Running a standard again between samples would also confirm the instrument has not drifted.

MARKING CRITERIA

MARKS	CRITERIA
4	Correct concentration with units, and a dilution and re measurement proposed with the reason that the reading lies outside the calibrated range.
3	Correct concentration and dilution proposed without a clear reason.
2	Correct concentration only, or a correct method with an arithmetic slip.
1	Correct relationship quoted with no usable value.

QUESTION 36 · STRUCTURE FROM THE SPECTRA · 4 MARKS

The molecular formula. $C_3H_6O_2$ has one degree of unsaturation, so there is one ring or one double bond.

The infrared evidence. A very broad absorption from 2500 to 3300 reciprocal centimetres is the hydroxyl of a carboxylic acid, broadened by hydrogen bonding. A strong absorption near 1710 is a carbon to oxygen double bond. The two together are a carboxyl group, and they rule out an ester, which shows the carbonyl but no broad hydroxyl band.

The nuclear magnetic resonance evidence. Three peaks in the ratio 3 to 2 to 1 means three hydrogen environments containing three, two and one hydrogen. That is a methyl group, a methylene group and one acidic hydrogen.

The structure. CH_3CH_2COOH, propanoic acid. Its three environments are the methyl, the methylene and the carboxyl hydrogen, in the ratio 3 to 2 to 1, and it accounts for all three carbons, six hydrogens and two oxygens.

MARKING CRITERIA

MARKS	CRITERIA
4	Correct structure named, with the infrared bands and the peak ratio each used as evidence and the alternative ester structure ruled out.
3	Correct structure with two pieces of evidence used.
2	Correct functional group identified from the infrared, structure not reached.
1	One spectroscopic feature correctly interpreted.

QUESTION 37 · SULFATE OR CARBONATE · 4 MARKS

The test. Add dilute hydrochloric acid to a small portion of the solid.

If it is a carbonate. It effervesces immediately, and the gas turns limewater milky, which confirms carbon dioxide.

If it is a sulfate. There is no effervescence. Dissolve a fresh portion in water, acidify with dilute hydrochloric acid and add barium chloride solution. A dense white precipitate of barium sulfate confirms sulfate. The acid is added first so that any carbonate present is destroyed and cannot give a false white precipitate of barium carbonate.

Ba^{2+} (aq) + SO_4^{2-} (aq) $\rightarrow$ $BaSO_4$ (s)

MARKING CRITERIA

MARKS	CRITERIA
4	A workable test described, both expected observations stated, a correct balanced equation given, and the acidification justified.
3	Test and both observations correct with a correct equation, no justification.
2	Test and one observation correct, or both observations with no equation.
1	A relevant reagent named.

QUESTION 38 · WHY ATOMIC ABSORPTION · 2 MARKS

At the guideline level lead is present at micrograms per litre: the guideline is 0.010 mg/L, which is 10 micrograms per litre. A gravimetric method would have to produce a precipitate heavy enough to weigh on an analytical balance, but a one litre sample at these levels holds only about ten micrograms of lead, less than the 0.1 mg that an analytical balance can resolve, so the result would be swamped by weighing error.

Atomic absorption measures the light absorbed by free atoms of one element at a wavelength specific to that element. It is both far more sensitive and far more selective, so it gives a usable result on a small sample without separating the lead from anything else first.

MARKING CRITERIA

MARKS	CRITERIA
2	Names sensitivity at low concentration and one further advantage such as selectivity or small sample size, with the gravimetric limitation identified.
1	States that atomic absorption is more sensitive with no supporting reason.

QUESTION 39 · WATER AGAINST SEDIMENT · 2 MARKS

The sediment assays 11.44 per cent lead by mass, which is roughly a hundred thousand milligrams per kilogram, while the water above it holds 23.8 mg/L. The sediment therefore holds the overwhelming majority of the lead in the system.

Lead compounds are sparingly soluble, so lead entering the river settles and accumulates in the sediment rather than staying dissolved. The sediment is both the reservoir and the record: it stores a history of the discharge that the water column, which is continually flushed, cannot. Treating the water alone would not address the source.

MARKING CRITERIA

MARKS	CRITERIA
2	Recognises that the sediment holds most of the lead, and explains this by low solubility and accumulation over time.
1	Recognises the difference in magnitude with no explanation.

Extended response · worked solutions

QUESTION 40 · MONITORING AND DOSING AGAINST KR 14 · 8 MARKS

The problem in chemical terms. The return line runs at pH 5.5 against a licence range of 6.5 to 8.5. That is one unit below the lower limit, so the hydronium concentration is about ten times the permitted maximum. The acid present is sulfuric acid, which is fully ionised in both steps at these concentrations.

The dosing chemistry. Sodium hydroxide or lime is dosed into the line to neutralise it:

Neutralisation

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

How the monitoring data would be used. Grab samples are taken from the return line at a fixed frequency and titrated against standardised 0.100 mol/L sodium hydroxide to a phenolphthalein endpoint. Each titre converts to an acid concentration, and the acid concentration multiplied by the line flow rate gives the acid load in moles per hour. The dosing rate is then set to match that load, with the stoichiometric two to one ratio built in. A continuous pH probe downstream of the dosing point provides the feedback that confirms the dose landed the pH inside the range.

Why titration is the right measurement here. A pH probe measures hydronium concentration at one instant. A titration measures total acid, which is what the dose must neutralise. Those are not the same quantity, and dosing against pH alone systematically underestimates the requirement where a weak acid is also present. Titration also gives a result traceable to a standard solution, which is what a regulator will accept as evidence of compliance.

The judgement. Titration based monitoring with feedback dosing is an appropriate control, because it measures the quantity the dose must match, it is accurate at the concentrations involved and it produces a defensible record. It should not be used alone.

The limitation. Grab sampling and titration are intermittent. A slug of acid released between samples passes into the river undetected and undosed, and the licence is breached in the interval whatever the average says. The control therefore depends on a continuous pH probe to catch excursions, with the titration programme calibrating the probe and providing the compliance record. A second limitation is that neutralising the acid does not remove its sulfate. The sulfate stays in solution, now as dissolved sodium sulfate, and still reaches the river, and KR 14 sets no limit on sulfate.

MARKING CRITERIA

Assess is a judgement verb. A response that describes a monitoring programme accurately and never says whether it is adequate caps in the middle band, however good the chemistry is.

MARKS	CRITERIA
7 to 8	Identifies the chemical problem quantitatively, including that one pH unit is a factor of ten. Gives a correct balanced neutralisation equation. Explains in full how titration data converts to an acid load and then to a dosing rate, and distinguishes total acid from instantaneous pH. Reaches an explicit judgement and defends it, and identifies a genuine limitation with its consequence for compliance.
5 to 6	Correct equation and a sound account of the monitoring and dosing. A judgement is reached and a limitation identified, but one of the two is asserted rather than defended, or the distinction between total acid and pH is missing.
3 to 4	Describes titration and dosing correctly at a general level. The equation may be present but unbalanced. A limitation is named without its consequence, and the judgement is implied rather than stated.
1 to 2	Some correct chemistry about neutralisation or pH, with little application to the monitoring programme and no judgement.

QUESTION 41 · IDENTIFYING THE UNLABELLED DRUM · 7 MARKS

What has to be distinguished. Ethanol, an alcohol. Ethanoic acid, a carboxylic acid. Ethyl ethanoate, an ester. All three are colourless liquids of similar volatility, so appearance settles nothing.

Test 1. Universal indicator or a pH probe on an aqueous portion

Ethanoic acid gives a pH of about 3, because it ionises partially in water. Ethanol and ethyl ethanoate give a pH close to 7. A single reading therefore identifies the acid outright, or eliminates it. This test goes first because it takes seconds, uses a drop of sample and splits the set.

Test 2. Add sodium carbonate solution to a fresh portion

If the first test suggested an acid, this confirms it: effervescence, and the gas turns limewater milky.

Confirming the acid

$2CH_3COOH\ (aq) + Na_2CO_3\ (aq) \rightarrow 2CH_3\ COONa\ (aq) + H_2O\ (l) + CO_2\ (g)$

Test 3. Smell, cautiously, and check solubility in water

Ethanol mixes with water in all proportions. Ethyl ethanoate is only slightly soluble and forms a separate layer, and carries the characteristic sweet solvent odour. This separates the remaining two, but it is judgement based, so it is indicative rather than conclusive.

Test 4. The instrumental technique. Infrared spectroscopy

This is what makes the identification certain, and it is run last because it is the slowest and needs an instrument.

- Ethanol: a broad strong absorption near 3300 reciprocal centimetres from the hydroxyl group, and no absorption near 1700.
- Ethanoic acid: a very broad absorption from 2500 to 3300 and a strong carbonyl absorption near 1710. Both bands together, which neither of the others shows.
- Ethyl ethanoate: a strong carbonyl absorption near 1740 and no broad hydroxyl band at all.

Why this order. Fast, cheap and non destructive first, slow and instrumental last, and each test performed only on the candidates that survive the previous one. A single infrared spectrum would in fact answer the question by itself, but the chemical tests cost minutes rather than instrument time, and a result confirmed by two independent methods is what an assay laboratory will sign.

MARKING CRITERIA

Design means the sequence matters. Three correct tests in an order that could not have been planned in advance loses the justification marks even when every observation is right.

MARKS	CRITERIA
7	A logical sequence of at least three tests including one instrumental technique. Every expected observation stated for every candidate. A correct balanced equation for a confirmatory test. The order justified by a property of the tests, such as speed, cost or destructiveness, and the certainty of the final identification addressed.
5 to 6	A workable sequence with an instrumental technique included and most observations stated. The order is justified in general terms, or the equation is present but unbalanced.
3 to 4	Relevant tests named with some correct observations. Little or no justification of the order, and the instrumental evidence described only loosely.
1 to 2	One relevant test with a correct observation, no sequence and no justification.

Where the extended marks sit. Two of these forty one items were worth seven marks or more, which is a fifth of Section II between them. They are also the questions students leave until the clock beats them.

Practice Paper 1, 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 12. Written to the NSW Chemistry Stage 6 Syllabus (2017), Modules 5 to 8, for students sitting the HSC in 2027 and 2028. A new Chemistry syllabus is first examined in HSC 2029. The paper matches the HSC specification in marks, section split and item count, and covers the four modules in roughly similar proportions. Every question uses the Kerrindal Works, an invented site, and every worked solution was recomputed from its inputs before printing. Organic names are written with the hyphens the syllabus uses.

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