
Student Number

Barker College

2024 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

90 copies

Write your Student Number at the top of this page
Section I – Multiple Choice
Choose the best response and fill in the response oval completely

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Start Here →

1	A ○	B ○	C ○	D ○	11	A ○	B ○	C ○	D ○
2	A ○	B ○	C ○	D ○	12	A ○	B ○	C ○	D ○
3	A ○	B ○	C ○	D ○	13	A ○	B ○	C ○	D ○
4	A ○	B ○	C ○	D ○	14	A ○	B ○	C ○	D ○
5	A ○	B ○	C ○	D ○	15	A ○	B ○	C ○	D ○
6	A ○	B ○	C ○	D ○	16	A ○	B ○	C ○	D ○
7	A ○	B ○	C ○	D ○	17	A ○	B ○	C ○	D ○
8	A ○	B ○	C ○	D ○	18	A ○	B ○	C ○	D ○
9	A ○	B ○	C ○	D ○	19	A ○	B ○	C ○	D ○
10	A ○	B ○	C ○	D ○	20	A ○	B ○	C ○	D ○

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Barker College

2024 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Staff Involved:

- **NJD - Mr Dumbleton**
- **DLM - Mrs McGuinness**
- **ETH – Miss Hannan**
- **RJP* - Mr Paynter**
- **KMT - Dr Terrett**

80 copies

General Instructions:

- Write your Student Number on all answer pages
- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A separate Periodic Table and Data Sheet are provided with this paper
- For questions in Section II, show all relevant working in questions involving calculations

Total marks:

100

Section I – 20 marks (pages 2 - 12)

- Attempt Questions 1 – 20
- Allow about 35 minutes for this section

Section II – 80 marks (pages 13 - 36)

- Attempt Questions 21 - 33
- Allow about 2 hours and 25 minutes for this section

Section I

20 marks
Attempt Questions 1 – 20
Allow about 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1 - 20

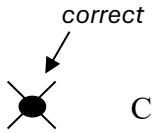
Sample 2 + 4 = A 2 B 6 C 8 D 9

A ○ B ○ C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows.



A ● B ⊗ C ○ D ○

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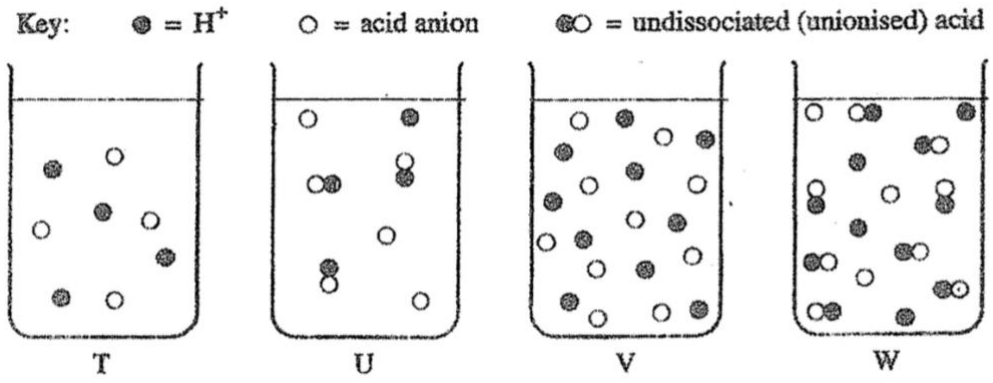
1. The following diagrams represent samples of four acids



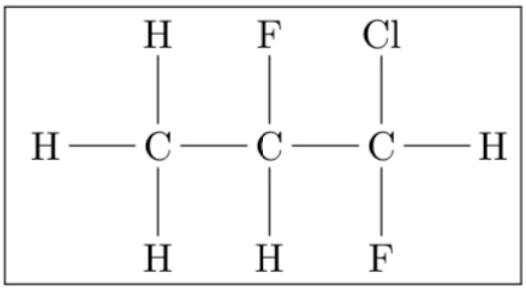
Which beaker contains a concentrated, weak acid?

A. T
B. U
C. V
D. W

2. What type of reaction is the conversion of ethene into ethane?

A. condensation
B. hydrogenation
C. hydrohalogenation
D. hydration

3. What is the name of the compound shown



A. 1-chloro-1,2-difluoropropane
B. 3-chloro-2,3-difluoropropane
C. 1,2-difluoro-1-chloropropane
D. 1-chloro-1,2-difluoropentane

4. Which of the following are isomers?

A. Propanal and butanal

B. Pentane and cyclopentane

C. Methyl ethanoate and propanoic acid

D. Butanone and butan-1-ol

5. Iron (III) ions can react with thiocyanate (SCN^-) ions to form the complex ion, iron thiocyanate ($Fe(SCN)^{2+}$), according to equation 1.

The addition of excess thiocyanate ions results in further reaction of the $Fe(SCN)^{2+}$ ion to form another complex ion, $Fe(SCN)_2^+$, according to equation 2.

The presence of $Fe(SCN)_2^+$ ion produces a deeper blood red solution.

1. $Fe^{3+}_{(aq)} + SCN^-_{(aq)} \rightleftharpoons Fe(SCN)^{2+}_{(aq)}$ $\quad K_{eq} = 890$

2. $Fe(SCN)^{2+}_{(aq)} + SCN\text{-}(aq) \rightleftharpoons Fe(SCN)_2^+{}_{(aq)}$ $\quad K_{eq} = 2.6$

Calculate the K_{eq} for the reaction below:

$$Fe^{3+}_{(aq)} + 2SCN^-_{(aq)} \rightleftharpoons Fe(SCN)_2^+{}_{(aq)}$$

A. 892.6

B. 2.9×10^{-3}

C. 2.3×10^{3}

D. 342.3

6. Consider the system:

$$HF_{(aq)} + H_2O_{(l)} \rightleftharpoons F^-_{(aq)} + H_3O^+_{(aq)}$$

Which of the following represents a conjugate acid-base pair present in this system?

A. $HF_{(aq)}/F^-_{(aq)}$

B. $HF_{(aq)}/ H_3O^+_{(aq)}$

C. $HF_{(aq)}/H_2O_{(l)}$

D. $F^-_{(aq)}/H_3O^+_{(aq)}$

7. Which of the following fragments could give rise to an ion peak in the mass spectrum of 1-chloro-2-methylpropane?

A. $[C_4H_9]^+$

B. $[CH_4]^+$

C. $[C_3H_9]^+$

D. $[CH_3Cl]^+$

8.

Indicator	*Colour & pH*	*Colour & pH*
Phenol Red	Yellow $\leq$ 6.8	Red $\geq$ 8.4
Methyl Orange	Red $\leq$ 3.1	Yellow $\geq$ 4.4

A small quantity of soil was added to 5 mL of pure water, stirred for 5 minutes, allowed to settle and filtered. When one sample of the filtrate was tested with phenol red, the colour turned yellow. When another sample was tested with methyl orange, the colour turned yellow.

What is the best conclusion about the soil?

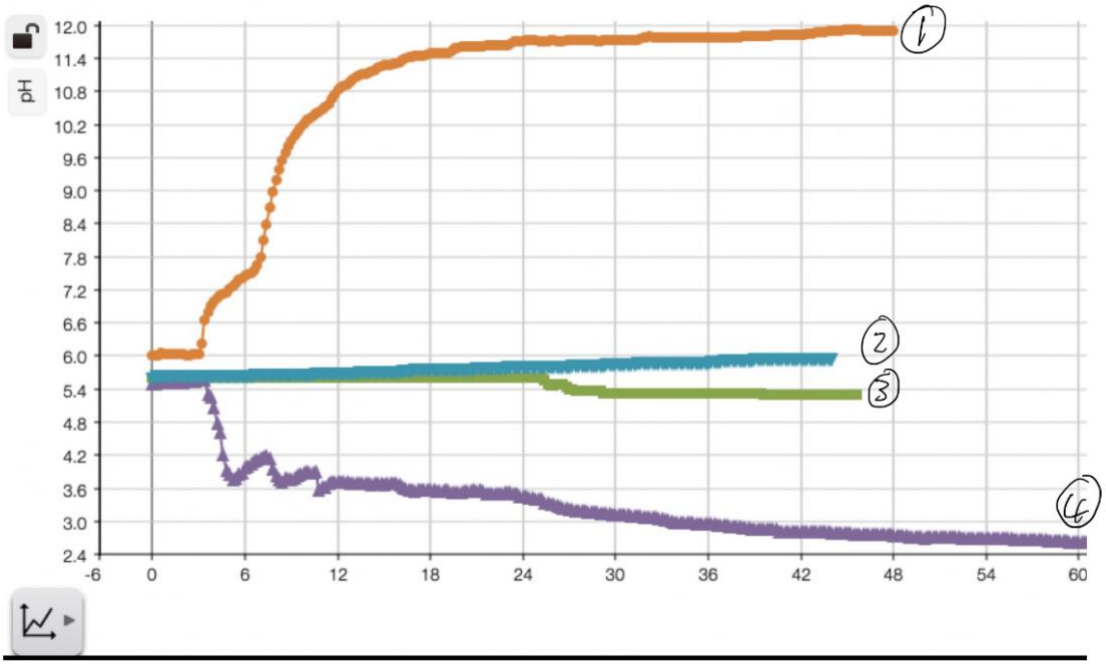
A. That it is slightly acidic and has a pH less than 8.4.

B. That it is slightly acidic and has a pH less than 6.8.

C. That it is slightly alkaline and has a pH less than 6.8.

D. That it is very acidic and has a pH less than 4.4.

9. An experiment to test buffers was carried out in class. Below is a screenshot of the pH curves obtained when buffered and unbuffered solutions were tested by adding drops of acid or base.



Identify the correct label for each of the graphs.

	1	*2*	*3*	*4*
A.	buffered solution with base added	unbuffered solution with base added	unbuffered solution with acid added	buffered solution with acid added
B.	unbuffered solution with base added	buffered solution with base added	buffered solution with acid added	unbuffered solution with acid added
C.	unbuffered solution with base added	buffered solution with acid added	buffered solution with base added	unbuffered solution with acid added
D.	buffered solution with acid added	unbuffered solution with acid added	unbuffered solution with base added	buffered solution with base added

10. Which sequence of reagents would be most suitable to convert 1-chloro-2-methylpropane to 2-methylpropene?

A. Concentrated H_2SO_4, then acidified MnO_4^-

B. Water with an acid catalyst then hydrogen with a platinum catalyst

C. Acidified MnO_4^- , then water with an acid catalyst

D. NaOH (aq), then concentrated H_2SO_4

11. At a certain temperature, the equilibrium constant, K, for the following reaction is 75.

$2O_{3(g)} \rightleftharpoons 3O_{2(g)}$

0.3 mol of O_3 and 1.5 mol of O_2 were introduced into a 5L reaction vessel. Which is the direction of the equilibrium shift and the reason for the shift?

	Direction Favoured	*Reason*
A.	Left	Q > K
B.	Left	Q < K
C.	Right	Q > K
D.	Right	Q < K

12. Consider the equilibrium process:

$CH_2CH_{2(g)} + H_{2(g)} \rightleftharpoons CH_3CH_{3(g)}$ $\Delta H = -136$ kJ/mol

Which of the following changes would increase the rate of the forward reaction AND cause the equilibrium to shift in the forward direction?

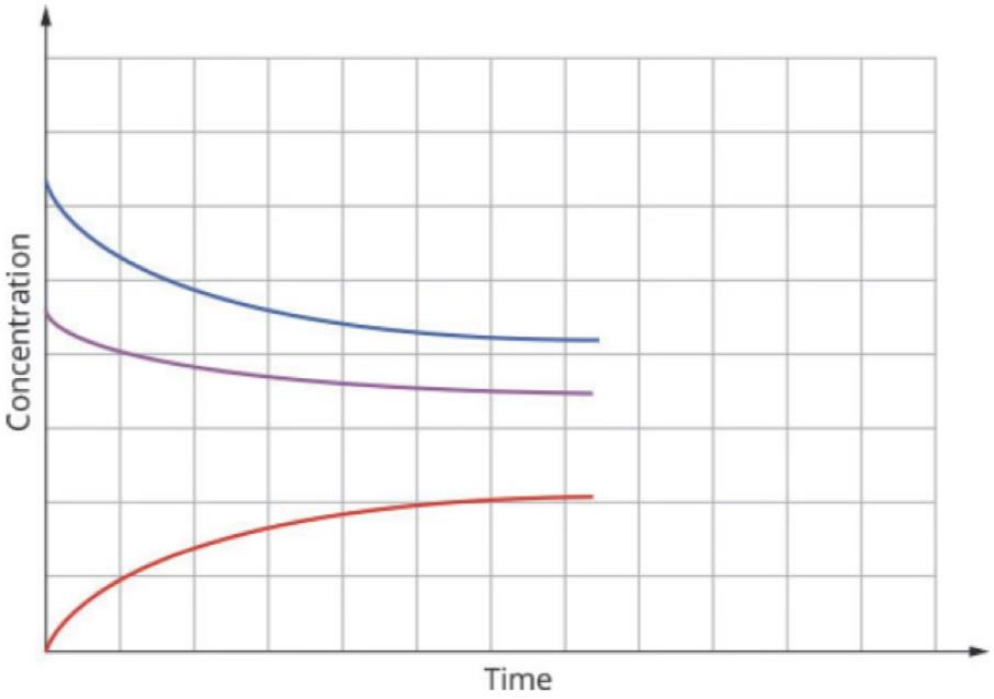
A. The temperature is decreased

B. The pressure is decreased

C. The concentration of H_2 in the equilibrium mixture is increased

D. The concentration of CH_3CH_3 in the equilibrium mixture is increased

13. The concentration of species in an equilibrium reaction are shown in the graph below.



A reaction that matches the changes shown in the graph is:

A. $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

B. $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$

C. $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

D. $PCl_{3(g)} + Cl_{2(g)} \rightleftharpoons PCl_{5(g)}$

14. Deuterium (symbol D) is an isotope of hydrogen. Water made from deuterium has the symbol D_2O and has similar properties to normal water.

D_2O ionises according to the equilibrium:

$D_2O_{(l)} \rightleftharpoons D^+_{(aq)} + OD^-_{(aq)}$ $\quad K_{eq} = 1.82 \times 10^{-16}$ at 25 °C

In a neutral solution of pure D_2O at 25°C, $[D^+]$, in mol/L, is:

A. 1.00×10^{-7}

B. 1.35×10^{-8}

C. 0.91×10^{-16}

D. 1.82×10^{-16}

15. A saturated solution of magnesium sulfate was placed in a beaker. Solid magnesium sulfate containing radioactive sulfur-35 was added to the solution. The beaker was left overnight and then the mixture was filtered.

Radioactive sulfur-35 would be expected to be found in which of the following?

A. the residue only

B. the filtrate only

C. Neither the residue nor the filtrate

D. Both the residue and filtrate

16. Which of the following statements best describes the primary differences between the Arrhenius and Brønsted-Lowry acid theories?

i. The Arrhenius theory defines acids as proton donors, while the Brønsted-Lowry theory defines acids as proton acceptors.

ii. The Arrhenius theory defines acids as substances that contain hydrogen and increase the concentration of hydrogen ions (H^+) in aqueous solutions, while the Brønsted-Lowry theory defines acids as proton donors.

iii. The Arrhenius theory applies only to reactions in aqueous solutions, while the Brønsted-Lowry theory applies to reactions in both aqueous and non-aqueous solutions.

iv. The Arrhenius theory defines acids and bases in terms of electron pair acceptors and donors, while the Brønsted-Lowry theory defines them in terms of proton donors and acceptors.

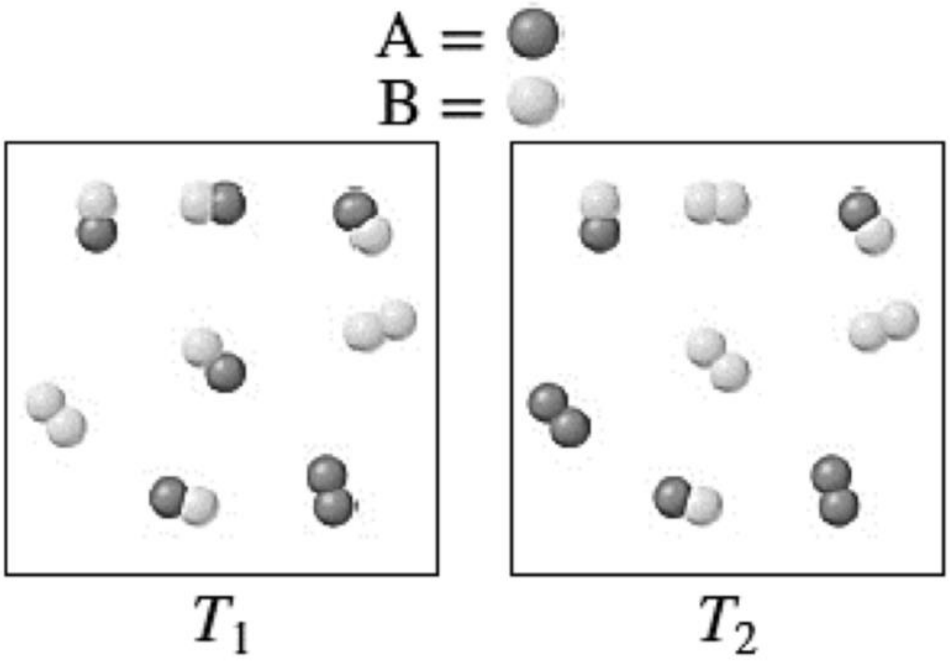
A. ii only

B. i and iii

C. ii and iii

D. iii and iv

17. The diagram below shows equilibrium mixtures of A_2, B_2 and AB at two different temperatures where $T_2 > T_1$.



Which of the following is true for the reaction $A_2 + B_2 \rightleftharpoons 2AB$?

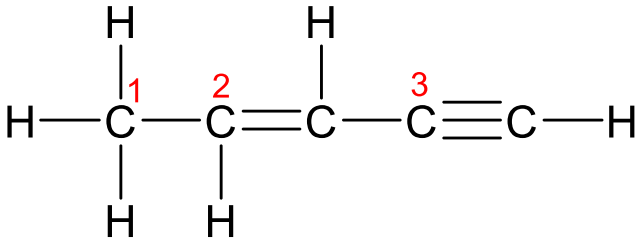
A. It is exothermic

B. It is endothermic

C. It is neither exothermic or endothermic

D. There is not enough information to determine whether it is exothermic or endothermic.

18. The shape around the numbered atoms in the molecule below are best described by which of the following options?



A. C1 linear, C2 trigonal planar, C3 tetrahedral

B. C1 tetrahedral, C2 trigonal planar, C3 linear

C. C1 trigonal planar, C2 linear, C3 tetrahedral

D. C1 tetrahedral, C2 linear, C3 trigonal planar

19. A student prepared an indicator from red cabbage by boiling red cabbage leaves in water for twenty minutes. They recorded the colour of the red cabbage indicator to obtain pH values at intervals of 2, and produced the following table.

pH	2	4	6	8	10	12	14
Colour of red cabbage indicator	red	pink	violet	blue	blue-green	green	yellow-green

The student used their prepared indicator to measure the pH of four different solutions of unknown concentration and recorded the following results.

HCl – pink	CH_3COOH - pink	$NaHCO_3$ - blue	NaOH – blue-green

Which of the following conclusions is consistent with the observed results?

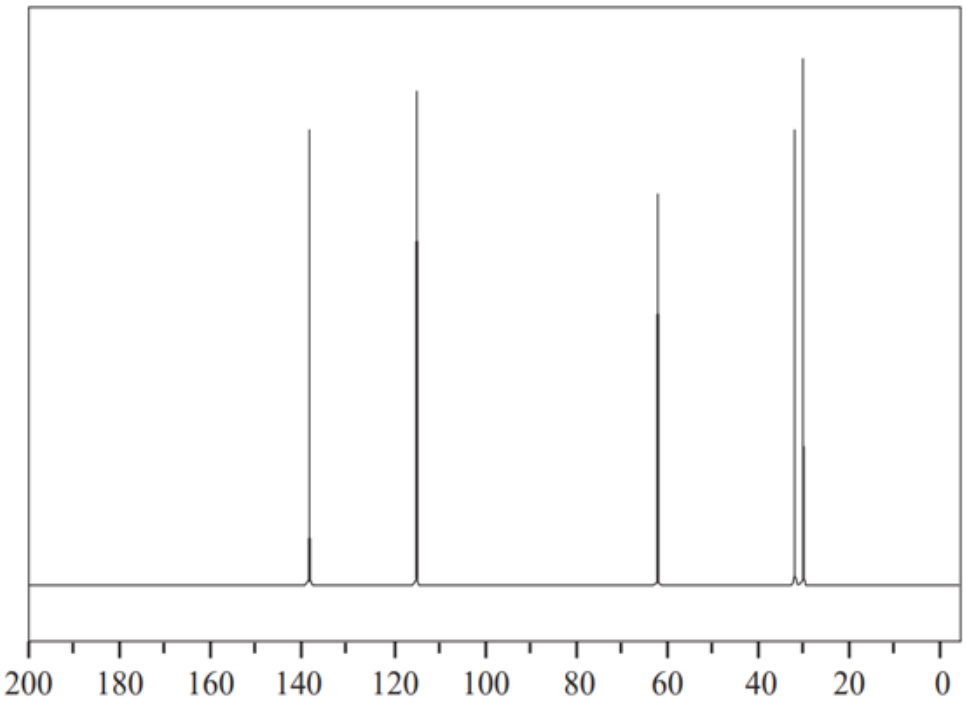
A. The concentrations of the HCl and the NaOH were both 0.0001 M.

B. The concentrations of the HCl and CH_3COOH were both 0.01 M.

C. The concentrations of the NaOH and $NaHCO_3$ were both 0.01 M.

D. The concentrations of the HCl and $NaHCO_3$ were both 0.01 M.

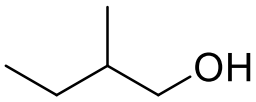
20. The ^{13}C NMR spectrum of an organic compound is shown below.



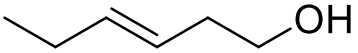
Data: SDBS Web, <https://sdbs.db.aist.go.jp>,
National Institute of Advanced Industrial Science and Technology

The organic compound could be:

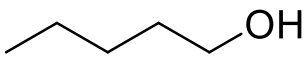
A



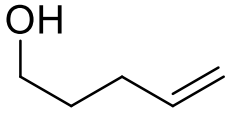
B



C



D



End of Section I

Student Number

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2024 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Section II Answer Booklet

80 marks

Attempt Questions 21 – 33

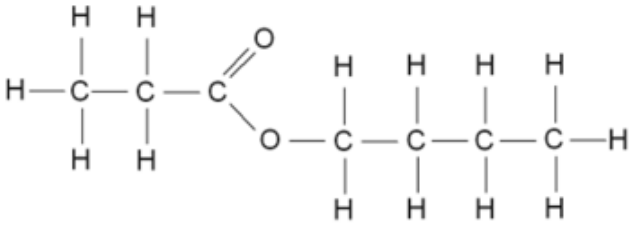
Allow about 2 hours and 25 minutes for this section.

Instructions

- Write your Student Number on all answer pages.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Question 21 (3 marks)

Complete the table below. **3**

	Name	Structural Diagram
A	2-chloro-3-methylpentanoic acid	
B	3-ethylhexan-2-amine	
C		

Student Number

Question 22 (7 marks)

Formic acid, a weak acid, has the formula HCOOH and its pKa is 3.75.

(a) Calculate the pH of a 0.25 M solution of formic acid at 25 °C. **3**

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(b) Formic acid can react with potassium hydroxide to produce a salt and water. Write an equation for this reaction. **1**

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(c) State whether you would expect the salt formed in part (b) to be acidic, neutral or basic. Explain your answer including an appropriate chemical equation. **3**

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Question 23 (4 marks)

50.0 mL of a solution of HCl with a pH of 3.0 was mixed with 30.0 mL of a solution of HNO_3 with a pH of 5.0.

Calculate the pH of the resultant solution. **4**

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Student Number

Question 24 (4 marks)

Ethanoic acid and ethanamide have similar molar masses but significantly different boiling points, as shown in the table below.

	Ethanoic acid	**Ethanamide**
MM (g/mol)	60	59
Boiling point (°C)	118	222

Explain the difference in the boiling points of these two compounds. Include a diagram in your response. **4**

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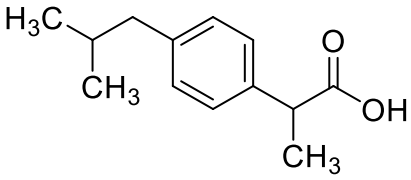
Question 25 (6 marks)

A chemist needed to check the composition of Nurofen tablets which contain the active ingredient, ibuprofen, a monoprotic acid.

A Nurofen tablet, with a mass of 256 mg, was crushed to a fine powder and then dissolved in water and transferred to a 125.0 mL volumetric flask, adding water accurately up to the mark. Four 25.0 mL aliquots of this solution were then titrated against a 0.00502 M standard solution of sodium hydroxide to a phenolphthalein end point. The sodium hydroxide titre values are shown below.

Titration Run	*Titre (mL)*
1	39.65
2	38.60
3	38.55
4	38.65



Ibuprofen

$C_{12}H_{17}COOH$

Molar Mass: 206.27 g/mol

(a) Write a balanced chemical equation for the reaction between ibuprofen and sodium hydroxide. **1**

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(b) Determine the percentage composition by mass of ibuprofen in the Nurofen tablet. **5**

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Student Number

Question 26 (7 marks)

Ammonia is manufactured industrially by the Haber process, the reaction equation being:

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} \qquad \Delta H = -92 \text{ kJ/mol}$$

(a) Write the equilibrium constant expression for this reaction. **1**

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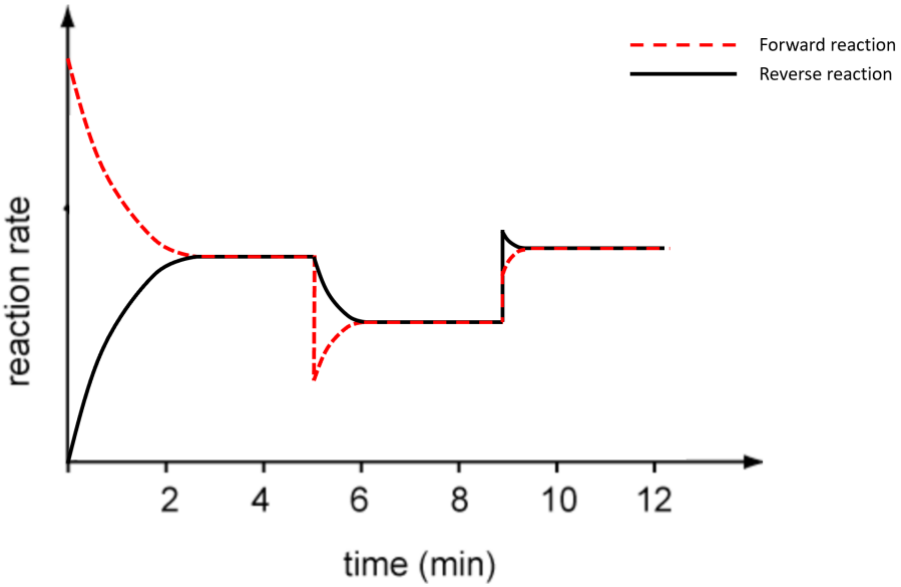
Some hydrogen, nitrogen and ammonia were sealed in a reaction vessel and the forward and reverse reaction rates were monitored for a period of time, as shown in the following graph:



Question 26 continues on page 20

Question 26 (continued)

(b) A change was made to the system at 5 minutes. Identify this change and use collision theory to explain the shapes of the curves between 5 and 8 minutes. **3**

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Question 26 continues on page 21

Student Number

Question 26 (continued)

(c) At 9 minutes, a temperature OR pressure change was applied to the system.

With reference to the graph above, and Le Chatelier's principle, justify which change was applied to the system at this time. **3**

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End of Question 26

Question 27 (9 marks)

Esters are the basis of many naturally occurring odours and are therefore widely used in the creation of artificial flavours. Methyl butanoate is a component in pineapple flavouring.

(a) Draw the structural formula equation for the formation of methyl butanoate from an alcohol and a carboxylic acid. Include all relevant reaction conditions. **2**

(b) Justify the need to reflux the reaction mixture to produce the ester product. **3**

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Question 27 continues on page 23

Student Number

Question 27 (continued)

(c) A chemist prepared methyl butanoate by combining 3.50 g of alcohol with 5.75 g of carboxylic acid. The mass of the product was found to be only 24% of the expected result.

What was the mass of the product extracted? **4**

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End of Question 27

Question 28 (7 marks)

Ionic compounds can form saturated solutions in water.

(a) Explain the processes involved when an ionic compound dissolves in water. Use diagrams to support your explanation. **3**

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(b) Lead(II) sulfate is an ionic compound used in lead-acid batteries. Write the equilibrium expression, K_{sp}, for a saturated solution of lead(II) sulfate. **1**

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Question 28 continues on page 25

Student Number

Question 28 (continued)

(c) Calculate the solubility of lead(II) sulfate at 25°C, in grams per 100 mL. **3**

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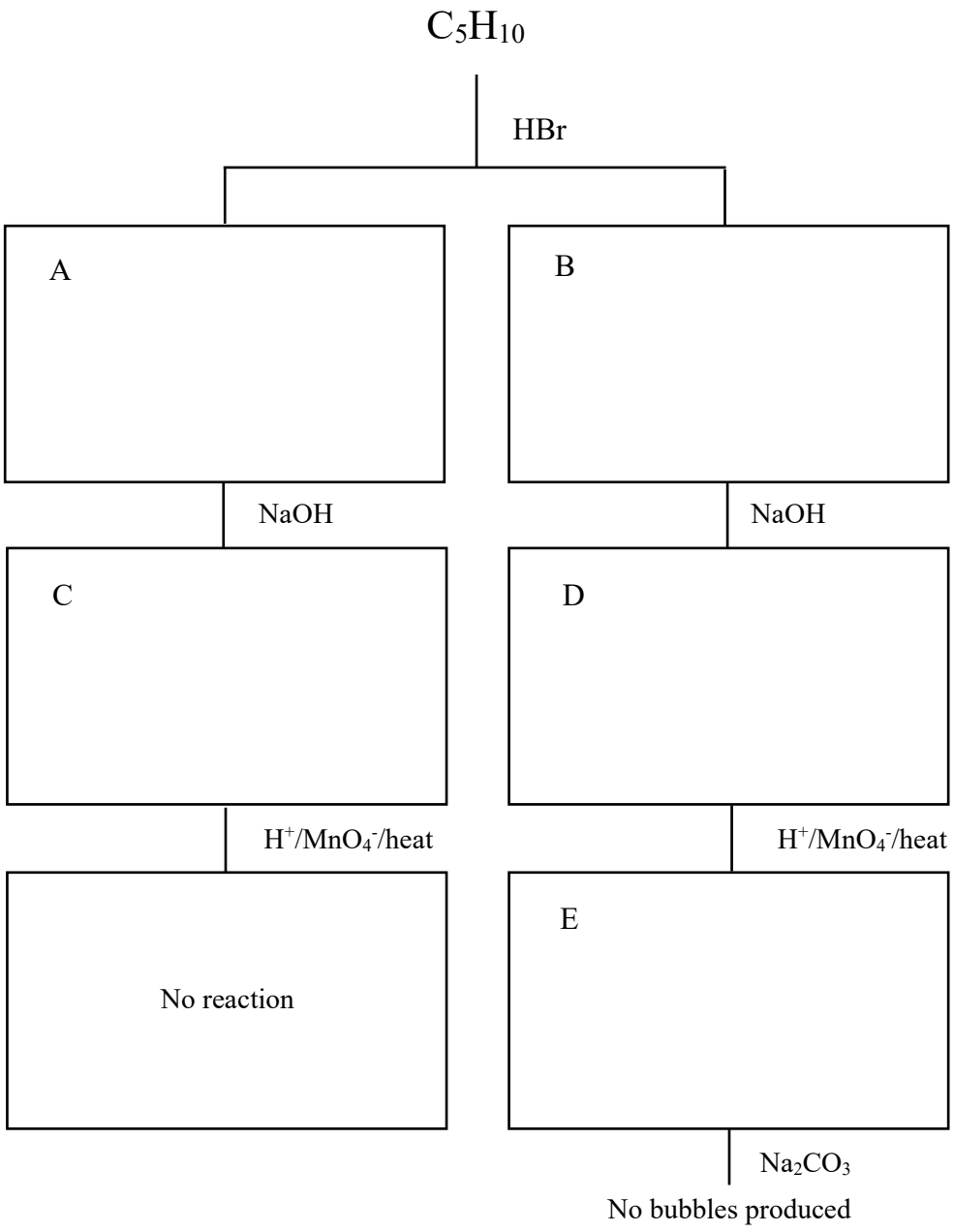
End of Question 28

Question 29 (5 marks)

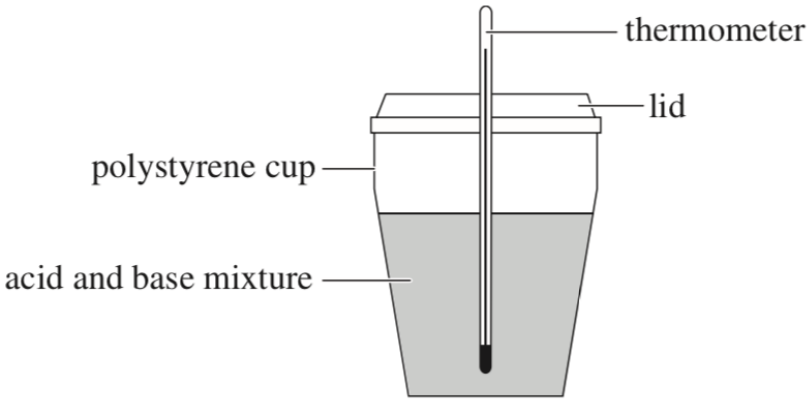
Draw the structural formula and name each of the molecules A to E in the reaction sequence below. **5**



Student Number

Question 30 (9 marks)

A group of students conducted an experiment using the calorimeter shown to determine the heat of neutralisation for an acid/base reaction.



The students added 200.0 mL of 1.00 mol L^{-1} nitric acid (HNO_3) to 200.0 mL of 1.00 mol L^{-1} potassium hydroxide (KOH) and stirred the mixture. An initial temperature of 22.7°C and a final temperature of 26.4°C were recorded.

(a) Calculate the molar enthalpy of neutralisation between nitric acid and potassium hydroxide. **3**

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Question 30 continues on page 28

Question 30 (continued)

(b) The theoretical enthalpy of neutralisation of any strong acid and strong base is -57 kJ/mol.

Explain the effect of ONE source of error on the calculated enthalpy of neutralisation. **3**

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(c) Describe an application of neutralisation reactions in everyday life. Include a balanced chemical equation in your answer. **3**

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End of Question 30

Student Number

Question 31 (4 marks)

Determine whether a precipitate will form when 50.0 mL of 0.052 M $Ba(OH)_2$ is mixed with 50.0 mL of 0.049 M Na_2SO_4. **4**

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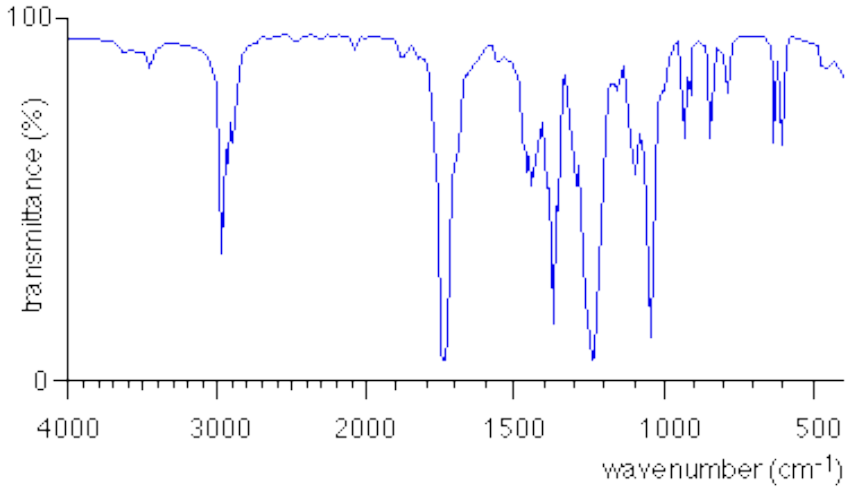
Question 32 (8 marks)

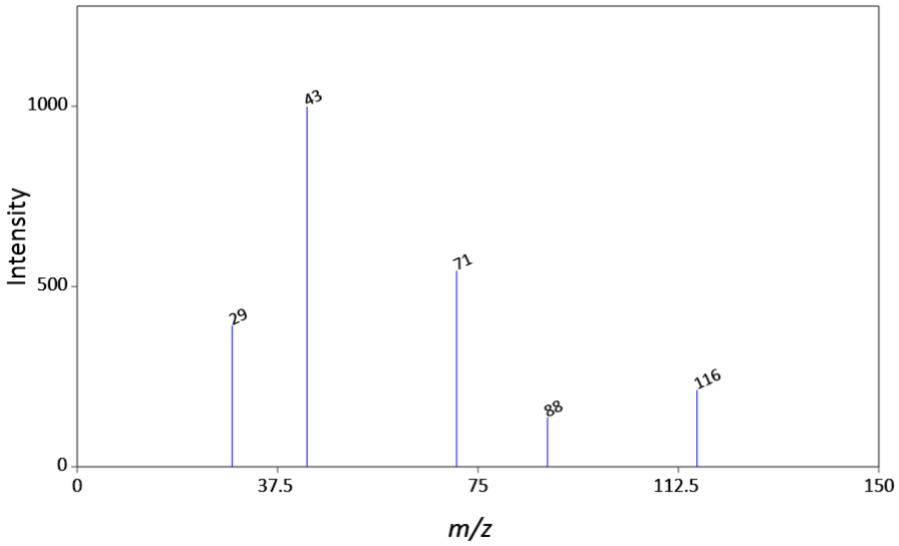
A range of analysis techniques were performed on a sample of a substance found in wine.
% composition analysis revealed C: 62.0%, H:10.4%, O:27.6%.

The spectra obtained from this analysis are presented below, along with ^{1}H NMR chemical shift data:

Infra-red:



Mass Spectrum:

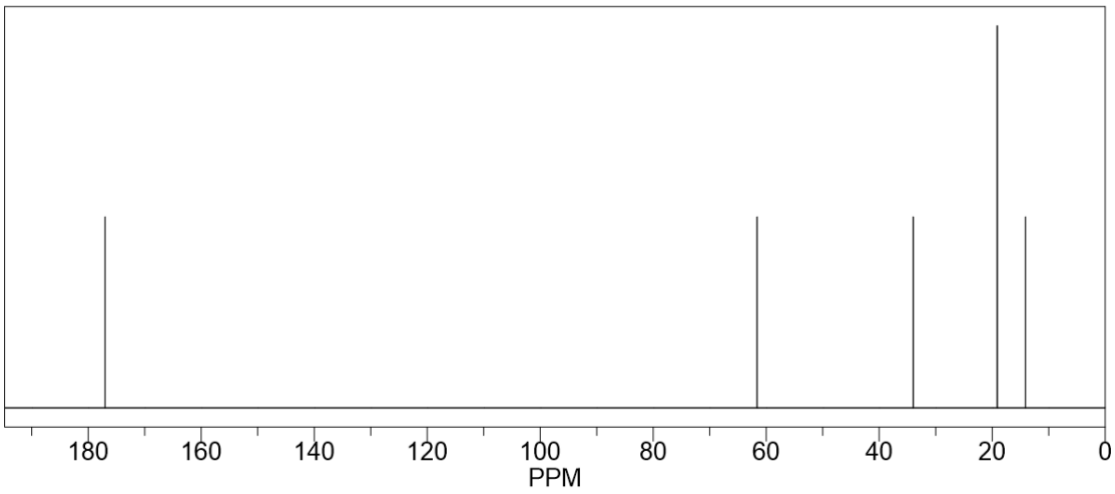


Question 32 continues on page 31

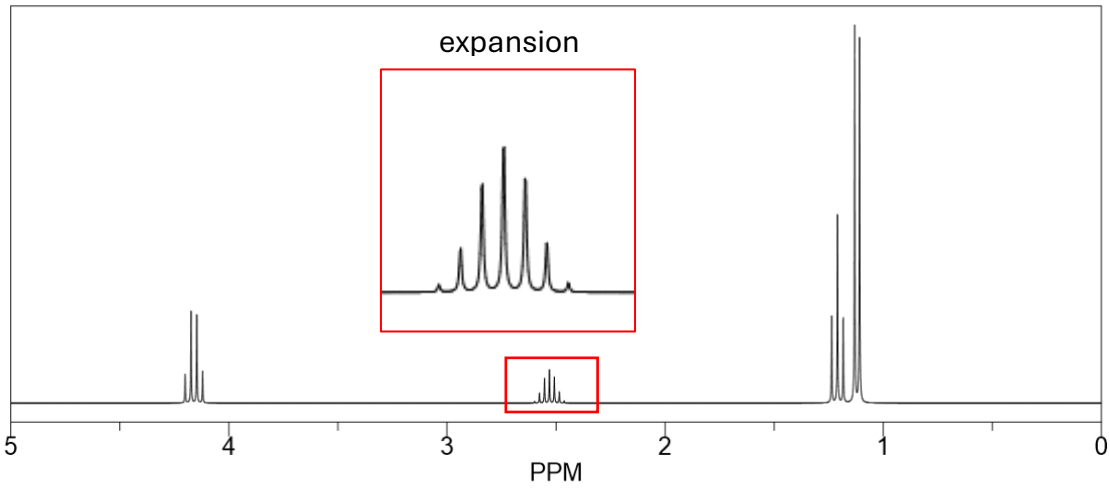
Student Number

Question 32 (continued)

^{13}C NMR:



^{1}H NMR:



Data from ^{1}H NMR spectrum

Chemical Shift	*Relative peak area*	*Splitting pattern*
1.1	6	doublet
1.2	3	triplet
2.6	1	septet
4.2	2	quartet

Question 32 continues on page 32

Question 32 (continued)

^{1}H NMR chemical shift data

Type of proton		δ/ppm
$Si(CH_3)_4$	(TMS)	0
R—CH_3		0.7–1.3
R—CH_2—R		1.2–1.5
R—CHR_2		1.5–2.0
H_3C—CO—	(aldehydes, ketones or esters)	2.0–2.5
—CH—CO—	(aldehydes, ketones or esters)	2.1–2.6
H_3C—O—	(alcohols or esters)	3.2–4.0
—CH—O—	(alcohols or esters)	3.3–5.1
R_2—CH_2—O—	(alcohols or esters)	3.5–5.0
R—OH		1–6
R_2C=CHR	(alkene)	4.5–7.0
R—CHO	(aldehyde)	9.4–10.0
R—COOH		9.0–13.0

(a) With reference to the percentage composition and the mass spectrum, determine the molecular formula of the compound. **1**

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Question 32 continues on page 33

Student Number

Question 32 (continued)

(b) Draw the structural formula of the compound and justify your decision by referring to data in all the spectra provided. **7**

End of Question 32

Question 33 (7 marks)

The labels and most of the information for five organic compounds in the laboratory store cupboard have been lost. The compounds are known to be pentane, pentan-1-ol, pentan-3-ol, pentan-3-one and pentanoic acid.

Use the clues below and the boiling point data in the table to identify the five compounds. Draw the structural formula of each compound (in the table below) and justify your identifications with reference to specific data, structural formulae and/or relevant chemical equations. **7**

Clues

1. The C-NMR of B has three peaks.
2. The C-NMR of C has three peaks.
3. A forms D by reaction with acidified MnO_4^-.
4. E forms B by reaction with acidified MnO_4^-.

Compound	Boiling Point
A	138°C
B	102°C
C	36.1°C
D	186°C
E	116°C

A	B	C
D	E	

Question 33 continues on page 35

Student Number

Question 33 (continued)

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End of Question 33

End of Paper

Section II Extra writing space

If you choose to use this space, clearly indicate what question you are answering.

✅YR 12 TRIAL CHEMISTRY Final 2 2024

Monday 5 August 2024 1:06 PM

YR 12 TRIAL CHEMISTR...

Student Number

Barker College

2024 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

90 copies

Write your Student Number at the top of this page
Section I - Multiple Choice
Choose the best response and fill in the response oval completely

Start Here →

1	A○	B○	C○	D●	11	A○	B○	C○	D●
2	A○	B●	C○	D○	12	A○	B○	C●	D○
3	A●	B○	C○	D○	13	A○	B●	C○	D○
4	A○	B○	C●	D○	14	A○	B●	C○	D○
5	A○	B○	C●	D○	15	A○	B○	C○	D●
6	A●	B○	C○	D○	16	A○	B○	C●	D○
7	A●	B○	C○	D○	17	A●	B○	C○	D○
8	A○	B●	C○	D○	18	A○	B●	C○	D○
9	A○	B●	C○	D○	19	A●	B○	C○	D○
10	A○	B○	C○	D●	20	A○	B○	C○	D●

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Student Number

Barker College

2024 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Staff Involved:

- NJD - Mr Dumbleton
- DLM - Mrs McGuinness
- ETH - Miss Hannan
- RJP* - Mr Paynter
- KMT - Dr Terrett

80 copies

General Instructions:

- Write your Student Number on all answer pages
- Reading time - 5 minutes
- Working time - 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A separate Periodic Table and Data Sheet are provided with this paper
- For questions in Section II, show all relevant working in questions involving calculations

Total marks:

100

Section I - 20 marks (pages 2 - 12)

- Attempt Questions 1 - 20
- Allow about 35 minutes for this section

Section II - 80 marks (pages 13 - 36)

- Attempt Questions 21 - 33
- Allow about 2 hours and 25 minutes for this section

Section 1

20 marks
Attempt Questions 1 – 20
Allow about 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1 - 20

Sample 2 + 4 = A 2 B 6 C 8 D 9

A ○ B ○ C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows.

correct ↙

A ● B ⊗ C ○ D ○

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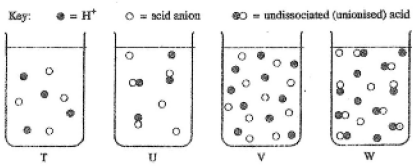
1. The following diagrams represent samples of four acids



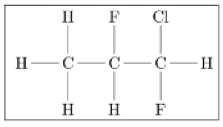
Which beaker contains a concentrated, weak acid?

A. T
B. U
C. V
D. W

2. What type of reaction is the conversion of ethene into ethane?

A. condensation
B. hydrogenation
C. hydrohalogenation
D. hydration

3. What is the name of the compound shown



A. 1-chloro-1,2-difluoropropane
B. 3-chloro-2,3-difluoropropane
C. 1,2-difluoro-1-chloropropane
D. 1-chloro-1,2-difluoropentane

4. Which of the following are isomers?

A. Propanal and butanal
B. Pentane and cyclopentane
C. Methyl ethanoate and propanoic acid
D. Butanone and butan-1-ol

5. Iron (III) ions can react with thiocyanate (SCN^-) ions to form the complex ion, iron thiocyanate (I $e(SCN)^{2+}$), according to equation 1.

The addition of excess thiocyanate ions results in further reaction of the $Fe(SCN)^{2+}$ ion to form another complex ion, $Fe(SCN)_2^+$, according to equation 2.

The presence of $Fe(SCN)_2^+$ ion produces a deeper blood red solution.

1. $Fe^{3+}_{(aq)} + SCN^-_{(aq)} \rightleftharpoons Fe(SCN)^{2+}_{(aq)}$ $K_{eq} = 890$

2. $Fe(SCN)^{2+}_{(aq)} + SCN^-_{(aq)} \rightleftharpoons Fe(SCN)_2^+_{(aq)}$ $K_{eq} = 2.6$

Calculate the K_{eq} for the reaction below:

$Fe^{3+}_{(aq)} + 2SCN^-_{(aq)} \rightleftharpoons Fe(SCN)_2^+_{(aq)}$

A. 892.6
B. 2.9×10^3
C. 2.3×10^3
D. 342.3

6. Consider the system:

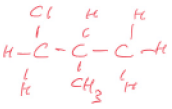
$HF_{(aq)} + H_2O_{(l)} \rightleftharpoons F^-_{(aq)} + H_3O^+_{(aq)}$

Which of the following represents a conjugate acid-base pair present in this system?

A. $HF_{(aq)}/F^-_{(aq)}$
B. $HF_{(aq)}/H_3O^+_{(aq)}$
C. $HF_{(aq)}/H_2O_{(l)}$
D. $F^-_{(aq)}/H_3O^+_{(aq)}$

7. Which of the following fragments could give rise to an ion peak in the mass spectrum of 1-chloro-2-methylpropane?

A. $[C_4H_9]^+$
B. $[CH_3]^-$
C. $[C_3H_9]^+$
D. $[CH_2Cl]^+$



8.

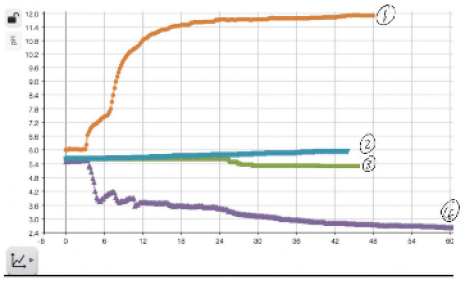
Indicator	*Colour & pH*	*Colour & pH*
Phenol Red	Yellow ≤ 6.8	Red ≥ 8.4
Methyl Orange	Red ≤ 3.1	Yellow ≥ 4.4

A small quantity of soil was added to 5 mL of pure water, stirred for 5 minutes, allowed to settle and filtered. When one sample of the filtrate was tested with phenol red, the colour turned yellow. When another sample was tested with methyl orange, the colour turned yellow.

What is the best conclusion about the soil?

A. That it is slightly acidic and has a pH less than 8.4.
B. That it is slightly acidic and has a pH less than 6.8.
C. That it is slightly alkaline and has a pH less than 6.8.
D. That it is very acidic and has a pH less than 4.4.

9. An experiment to test buffers was carried out in class. Below is a screenshot of the pH curves obtained when buffered and unbuffered solutions were tested by adding drops of acid or base.



Identify the correct label for each of the graphs.

	1	*2*	*3*	*4*
A.	buffered solution with base added	unbuffered solution with base added	unbuffered solution with acid added	buffered solution with acid added
B.	unbuffered solution with base added	buffered solution with base added	buffered solution with acid added	unbuffered solution with acid added
C.	unbuffered solution with base added	buffered solution with acid added	buffered solution with base added	unbuffered solution with acid added
D.	buffered solution with acid added	unbuffered solution with acid added	unbuffered solution with base added	buffered solution with base added

10. Which sequence of reagents would be most suitable to convert 1-chloro-2-methylpropane to 2-methylpropene?

A. Concentrated H_2SO_4, then acidified MnO_4^-
B. Water with an acid catalyst then hydrogen with a platinum catalyst
C. Acidified MnO^-, then water with an acid catalyst
D. NaOH (aq), then concentrated H_2SO_4

11. At a certain temperature, the equilibrium constant, K_c for the following reaction is 75.

$2O_{3(g)} \rightleftharpoons 3O_{2(g)}$

0.3 mol of O_3 and 1.5 mol of O_2 were introduced into a 5L reaction vessel. Which is the direction of the equilibrium shift and the reason for the shift?

	Direction Favoured	*Reason*
A.	Left	$Q > K$
B.	Left	$Q < K$
C.	Right	$Q > K$
D.	Right	$Q < K$

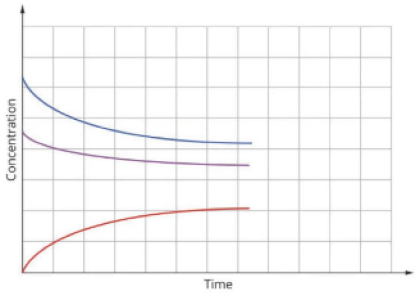
12. Consider the equilibrium process:

$CH_2CH_{2(g)} + H_{2(g)} \rightleftharpoons CH_3CH_{3(g)}$ $\Delta H = -136$ kJ/mol

Which of the following changes would increase the rate of the forward reaction AND cause the equilibrium to shift in the forward direction?

A. The temperature is decreased
B. The pressure is decreased
C. The concentration of H_2 in the equilibrium mixture is increased
D. The concentration of CH_3CH_3 in the equilibrium mixture is increased

13. The concentration of species in an equilibrium reaction are shown in the graph below.



A reaction that matches the changes shown in the graph is:

A. $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$
B. $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$
C. $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$
D. $PCl_{3(g)} + Cl_{2(g)} \rightleftharpoons PCl_{5(g)}$

14. Deuterium (symbol D) is an isotope of hydrogen. Water made from deuterium has the symbol D_2O and has similar properties to normal water.

D_2O ionises according to the equilibrium:

$D_2O_{(l)} \rightleftharpoons D^+_{(aq)} + OD^-_{(aq)} \quad K_{eq} = 1.82 \times 10^{-16}$ at 25 °C

In a neutral solution of pure D_2O at 25°C, $[D^+]$, in mol/L, is:

A. 1.00×10^{-7}
B. 1.35×10^{-8}
C. 0.91×10^{-16}
D. 1.82×10^{-16}

15. A saturated solution of magnesium sulfate was placed in a beaker. Solid magnesium sulfate containing radioactive sulfur-35 was added to the solution. The beaker was left overnight and then the mixture was filtered.

Radioactive sulfur-35 would be expected to be found in which of the following?

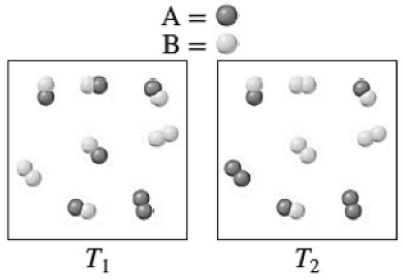
A. the residue only
B. the filtrate only
C. Neither the residue nor the filtrate
D. Both the residue and filtrate

16. Which of the following statements best describes the primary differences between the Arrhenius and Brønsted-Lowry acid theories?

i. The Arrhenius theory defines acids as proton donors, while the Brønsted-Lowry theory defines acids as proton acceptors.
ii. The Arrhenius theory defines acids as substances that contain hydrogen and increase the concentration of hydrogen ions (H^+) in aqueous solutions, while the Brønsted-Lowry theory defines acids as proton donors.
iii. The Arrhenius theory applies only to reactions in aqueous solutions, while the Brønsted-Lowry theory applies to reactions in both aqueous and non-aqueous solutions.
iv. The Arrhenius theory defines acids and bases in terms of electron pair acceptors and donors, while the Brønsted-Lowry theory defines them in terms of proton donors and acceptors.

A. ii only
B. i and iii
C. ii and iii
D. iii and iv

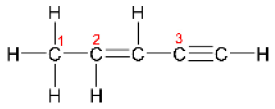
17. The diagram below shows equilibrium mixtures of A_2, B_2 and AB at two different temperatures where $T_2 > T_1$



Which of the following is true for the reaction $A_2 + B_2 \rightleftharpoons 2AB$?

A. It is exothermic
B. It is endothermic
C. It is neither exothermic or endothermic
D. There is not enough information to determine whether it is exothermic or endothermic.

18. The shape around the numbered atoms in the molecule below are best described by which of the following options?



A. C1 linear, C2 trigonal planar, C3 tetrahedral
B. C1 tetrahedral, C2 trigonal planar, C3 linear
C. C1 trigonal planar, C2 linear, C3 tetrahedral
D. C1 tetrahedral, C2 linear, C3 trigonal planar

19. A student prepared an indicator from red cabbage by boiling red cabbage leaves in water for twenty minutes. They recorded the colour of the red cabbage indicator to obtain pH values at intervals of 2, and produced the following table.

pH	2	4	6	8	10	12	14
Colour of red cabbage indicator	red	pink	violet	blue	blue-green	green	yellow-green

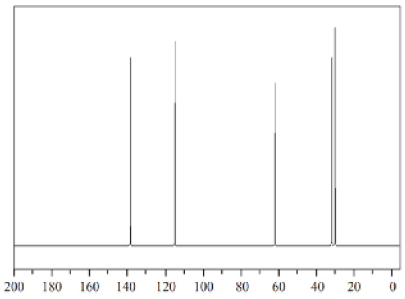
The student used their prepared indicator to measure the pH of four different solutions of unknown concentration and recorded the following results.

HCl – pink	CH_3COOH - pink	$NaHCO_3$ - blue	NaOH – blue-green

Which of the following conclusions is consistent with the observed results?

A. The concentrations of the HCl and the NaOH were both 0.0001 M.
B. The concentrations of the HCl and CH_3COOH were both 0.01 M.
C. The concentrations of the NaOH and $NaHCO_3$ were both 0.01 M.
D. The concentrations of the HCl and $NaHCO_3$ were both 0.01 M.

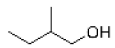
20. The ^{13}C NMR spectrum of an organic compound is shown below.



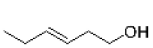
Data: SDBS Web, <https://sdbs.db.aist.go.jp>,
National Institute of Advanced Industrial Science and Technology

The organic compound could be:

A



B



C

D

End of Section I

Student Number

Barker College

2024 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Section II Answer Booklet

80 marks

Attempt Questions 21 - 33

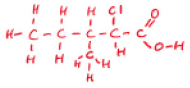
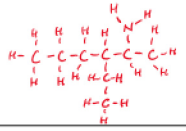
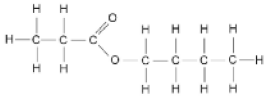
Allow about 2 hours and 25 minutes for this section.

Instructions

- Write your Student Number on all answer pages.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Question 21 (3 marks)

Complete the table below. 3

	Name	Structural Diagram
A	2-chloro-3-methylpentanoic acid	
B	3-ethylhexan-2-amine	
C	butyl propanoate	

marks	Question 21
3	All structural formulae and the naming correct
2	
1	

Some students forgot to number from the functional group in A

Student Number

Question 22 (7 marks)

Formic acid, a weak acid, has the formula HCOOH and its pKa is 3.75.

(a) Calculate the pH of a 0.25 M solution of formic acid at 25 °C. 3

$K_a = 10^{-pK_a}$

$K_a = 10^{-3.75}$ ✓

$K_a = 1.77827941 \times 10^{-4}$

$pH = -\log 6.66\ldots \times 10^{-3}$ ✓

$pH = 2.18$

$HCOOH \rightleftharpoons HCOO^- + H^+$

$K_a = \frac{[HCOO^-][H^+]}{[HCOOH]}$

As $[HCOO^-] = [H^+] = x$ ✓ As $x \ll 0.25$ IT CAN BE IGNORED

$[HCOOH] = 0.25 - x$

$1.77827941 = \frac{x^2}{0.25}$

$x = 6.66\ldots \times 10^{-3}$ M

(b) Formic acid can react with potassium hydroxide to produce a salt and water. Write an equation for this reaction. 1

$HCOOH_{(aq)} + KOH_{(aq)} \rightarrow KHCOO_{(aq)} + H_2O_{(l)}$

(c) State whether you would expect the salt formed in part (b) to be acidic, neutral or basic. Explain your answer including an appropriate chemical equation. 3

$HCOO^-$ is the conjugate base of the weak formic acid. It is relatively strong and is able to abstract a proton from water $HCOO^- + H_2O \rightleftharpoons HCOOH + OH^-$ The excess OH^- ions make the solution BASIC

K^+ ions DO NOT REACT WITH WATER.

mark	Question 22 A
3	correct answer and working out. States the assumption that x << 0.25 so can be ignored
2	One mistake
1	Two mistakes

Some students still forgetting to state the assumption.

Question 22b - had to include states.

mark	Question 22 c
3	States salt is basic, has correct equation showing hydroxide ions produced describes how the formate ion is a relatively strong conjugate base of the weak formic acid.
2	Two of the above
1	One of the above

They did not need to comment on potassium ion this time but it is encouraged they do.

Question 23 (4 marks)

50.0 mL of a solution of HCl with a pH of 3.0 was mixed with 30.0 mL of a solution of HNO_3 with a pH of 5.0.

Calculate the pH of the resultant solution. 4

HCl - $[H^+] = 10^{-3.0} = 1 \times 10^{-3}$ M

HNO_3 - $[H^+] = 10^{-5.0} = 1 \times 10^{-5}$ M

$n_{HCl} = cV = (1 \times 10^{-3})(50 \times 10^{-3}) = 5 \times 10^{-5}$ mol

$n_{HNO_3} = cV = (1 \times 10^{-5})(30 \times 10^{-3}) = 3 \times 10^{-9}$ mol

TOTAL moles ACID = 5.03×10^{-5} mol

TOTAL volume = 30mL + 50mL

$[H^+] = \frac{n}{V} = \frac{5.03 \times 10^{-5}}{80 \times 10^{-3}} = 6.2875 \times 10^{-4}$ M

pH = $-\log[H^+]$ = 3.2

16

mark	Question 23
4	works out [] from pH Uses n=cV to work out moles Adds moles of acid together Divides by total volume to find concentration Finds pH
3	One mistake
2	Two mistakes
1	3 mistakes

Some students got the correct pH but had thought it was a limiting reagent problem so subtracted small value from large value - so lost a mark.

Student Number

Question 24 (4 marks)

Ethanoic acid and ethanamide have similar molar masses but significantly different boiling points, as shown in the table below.

	Ethanoic acid	Ethanamide
MM (g/mol)	60	59
Boiling point (°C)	118	222

Explain the difference in the boiling points of these two compounds. Include a diagram in your response. 4

ETHANOIC ACID

ETHANAMIDE

INTRAMOLECULAR forces

DISPERSION + DIPOLE/DIPOLE

+ HYDROGEN BONDS

H-BONDS

HYDROGEN BONDS

Ethanamide, like ethanoic acid, has a carbonyl group which enables HYDROGEN BONDING with the H of an AMINE group on the neighbouring molecule.

Ethanamide intermolecular forces are also DISPERSION + DIPOLE/DIPOLE + HYDROGEN BONDS but as there are 2 H's on the N atom of ethanamide and only 1 H on the hydroxyl group of ethanoic acid it means ethanamide is able to form MORE HYDROGEN BONDS. Hence more energy is needed to overcome these intermolecular forces, explaining the higher bp of 222°C for ethanamide compared to 118°C for ethanoic acid.

17

mark	Question 23
4	• Correct type of bonding between molecules (H-bond, dipole-dipole and dispersion) • Discussion of H-bonds providing the strongest IMF and most affecting boiling point • Discussion of the greater amount of H-bonding possible with amide than carboxylic acid resulting meaning more energy required to break IMF and therefore having a in higher BP • Diagram has to show H-bonds between at least one class of molecules.
3	One mistake
2	Two mistakes
1	3 mistakes

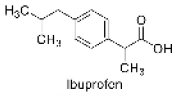
Main issue was diagrams not showing H bonds. Just structures given for each molecule. Best answers indicated dispersion and dipole-dipole were present in addition to H-bonding.

Question 25 (6 marks)

A chemist needed to check the composition of Nurofen tablets which contain the active ingredient, ibuprofen, a monoprotic acid.

A Nurofen tablet, with a mass of 256 mg, was crushed to a fine powder and then dissolved in water and transferred to a 125.0 mL volumetric flask, adding water accurately up to the mark. Four 25.0 mL aliquots of this solution were then titrated against a 0.00502 M standard solution of sodium hydroxide to a phenolphthalein end point. The sodium hydroxide titre values are shown below.

Titration Run	*Titre (mL)*
1	39.65
2	38.60
3	38.55
4	38.65



Ibuprofen
$C_{12}H_{17}COOH$
Molar Mass: 206.27 g/mol

(a) Write a balanced chemical equation for the reaction between ibuprofen and sodium hydroxide. 1

$C_{12}H_{17}COOH + NaOH \rightarrow NaC_{12}H_{17}COO + H_2O$

(b) Determine the percentage composition by mass of ibuprofen in the Nurofen tablet. 5

$n_{NaOH} = cV$

$V = \frac{39.60 + 38.55 + 38.65}{3}$ $V = 38.60$

$= (0.00502)(38.60 \times 10^{-3})$

$= 1.93772 \times 10^{-4}$

$C_{13}H_{18}O_2 : NaOH$ is 1:1 $\therefore$ 1.93772×10^{-4} mol of ibuprofen in 25 mL

1.93772×10^{-4} mol in 25 mL

x mol in 125 mL

$x = 9.6886 \times 10^{-4}$ mol

$MM_{C_{13}H_{18}O_2}$

$MM = (12.01 \times 13) + (1.008 \times 18) + (16 \times 2)$

$MM = 156.13 + 18.144 + 32$

$MM = 206.274$

$m = nMM$

$m = (9.6886 \times 10^{-4})(206.274)$

$m = 0.19985\ g$

$m = 199.85\ mg$

% composition $= \frac{199.85}{256} \times 100$

$= 78.1\%$

18

Balanced equation was generally well done.

mark	Question 23
5	Correct titre and moles of NaOH Ibuprofen calc is 5x NaOH Mass of ibuprofen %composition of tablet 3 sig fig
4	One mistake
3	Two mistakes
2	Three mistakes
1	Any relevant info

Fairly well done. Students either knew it or they did not.
Main issue was not multiplying mol in 25ml by 5 to get the moles in 125ml
Was possible to get the avg titre incorrect and still get 4 marks.

Student Number

Question 26 (7 marks)

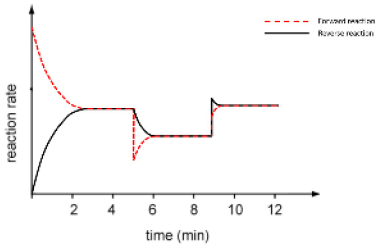
Ammonia is manufactured industrially by the Haber process, the reaction equation being:

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ $\Delta H = -92$ kJ/mol

(a) Write the equilibrium constant expression for this reaction. 1

$K = \frac{[NH_3]^2}{[N_2][H_2]^3}$

Some hydrogen, nitrogen and ammonia were sealed in a reaction vessel and the forward and reverse reaction rates were monitored for a period of time, as shown in the following graph:



Question 26 continues on page 20

19

Question 26 (continued)

(b) A change was made to the system at 5 minutes. Identify this change and use collision theory to explain the shapes of the curves between 5 and 8 minutes. **3**

FORWARD REACTION RATE DECREASED DRAMATICALLY INDICATING [REACTANTS] has decreased ∴ more product molecules to collide and reverse reaction would be favoured. As product molecules concentration decreases, the rate of the reverse reaction decreases due to fewer collisions. The increasing number of reactant molecules means the frequency of collisions would ↑ and the rate of the forward reaction would ↑

Question 26 continues on page 21

mark	Question 23
3	Changes was decrease in reactant/s with reasoning about initial changes in rate and favouring of one direction over other States points of collision theory in answer Described how changing amounts of reactants and products AFTER initial change resulted in a return to equilib with reference to collision theory.
2	Incorrect attribution of change agent or favouring of reaction direction or incomplete use of collision theory to explain return to equilib after initial change.
1	Incorrect attribution of change agent and/or favouring of reaction direction and/or incomplete use of collision theory to explain return to equilib after initial change.

Main issue was poor description of changes in reactant and product concs and how collision theory could explain the return to equilib.
Many students couldn't identify that the smaller change in initial rate indicated which direction was favoured, instead looking at which line increased rate after the initial change.

Student Number

Question 26 (continued)

(c) At 9 minutes, a temperature OR pressure change was applied to the system.

With reference to the graph above, and Le Chatelier's principle, justify which change was applied to the system at this time. **3**

At 9 minutes the rate of both the forward and reverse reactions increased which is consistent with an INCREASE IN TEMPERATURE. It can also be seen from the graph that the ENDOTHERMIC reverse reactions rate increased more, this is also predicted by LCP which states that if the temperature is changed the system shifts to minimise the change, ie ↑ T of system and the reaction which ↓ T of the system will be favoured, that is always the endothermic reaction.

molecules moving faster ∴ more collisions.

As the number of product molecules decreases, the chance for collisions decreases and the rate ↓. With more reactant molecules the rate of the forward reaction ↑ until a new equilibrium is reached and the rate of forward = rate of the reverse reaction.

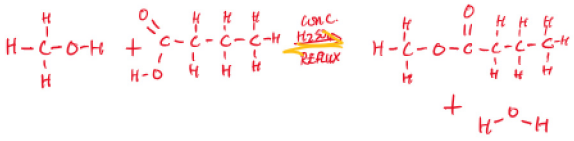
mark	Question 23
3	Changes was increase in temp Correct reasoning about initial changes in rate and favouring of one direction over other Referred to Le Chat theory
2	Incorrect attribution of change agent or incorrect reasoning or incomplete reference to Le Chat
1	Incorrect attribution of change agent and/or incorrect reasoning and/or incomplete reference to Le Chat

Like the previous question, many students couldn't correctly interpret the initial changes to identify which direction had been favoured.

Question 27 (9 marks)

Esters are the basis of many naturally occurring odours and are therefore widely used in the creation of artificial flavours. Methyl butanoate is a component in pineapple flavouring.

(a) Draw the structural formula equation for the formation of methyl butanoate from an alcohol and a carboxylic acid. Include all relevant reaction conditions. 2



(b) Justify the need to reflux the reaction mixture to produce the ester product. 3

Esterification is very slow at room temperature so heat is needed to ↑ reaction rate. Volatile reactants and products would be lost during heating so the Liebig condenser is used so that the volatile substances drip back down into the reaction vessel. This increases the yield of the ester and prevents flammable alcohol reactant vapours from reaching the naked flame in the event of a burner being used.

Question 27 continues on page 23

Criteria (DLM)	Mark
• Correct structural formula for reactants and products • Correct arrow style • Correct reaction conditions	2
2 of the above	1

Marker comments: Mixed response. Very common for student to use a single arrow, forget to show water as a product, or not include any, or correct reaction conditions. Only a handful of student could not correctly draw the ester correctly. Great to see people showing all bonds and all hydrogens in their molecular structures.

Criteria (DLM)	Mark
• Identifies 3 features of reflux and justifies their use	3
• Identifies 2 features of reflux and justifies their use • Identifies 3 features of reflux	2
• Identifies 1 of reflux and justifies its use • 2 pieces of relevant information	1

Marker comments: Mixed response. Many students were able to identify features but did not justify the specific reason. Most people described the volatility of reactants and products and the need to condense with an open condenser. Very few referred to the use of conc. H_2SO_4 as a dehydrating agent and its ability to shift equilibrium to the right.

Student Number

Question 27 (continued)

(c) A chemist prepared methyl butanoate by combining 3.50 g of alcohol with 5.75 g of carboxylic acid. The mass of the product was found to be only 24% of the expected result.

What was the mass of the product extracted? 4

3.50 g of methanol, 5.75 g butanoic acid

$MM_{CH_3OH} = 32.042\ g/mol$ $MM_{C_3H_8COOH} = 88.104\ g/mol$

$n_{CH_3OH} = \frac{m}{MM} = \frac{3.50}{32.042} = 0.1092316\ mol$ $n_{C_3H_8COOH} = \frac{5.75}{88.104} = 0.0652637\ mol$

∴ the Butanoic acid is the LIMITING REAGENT, as a 1:1 reaction ratio

0.0652637 mol of methyl butanoate produced. $MM_{C_5H_{10}O_2}$

Theoretical mass of product = nMM 60.05 + 10.08 + 32

$= (0.0652637)(102.13)$

$= 6.6653817\ g$

100% → 6.6653817 g

∴ 24% → x

mass of product = 1.60 g

End of Question 27

Criteria (DLM)	Mark
All major steps completed correctly with the correct yield obtained	4
All major steps completed with 1 minor error	3
2 major steps completed correctly	2
Some relevant information	1

Marker comments: Generally well done. Most students were able to determine the number of moles however a common error was incorrect determination of limiting reagent, with many students subtracting moles of butanoic acid from moles of methanol to determine moles of ester formed. If incorrect moles of ester determined, this was regarded as an incorrect major step.

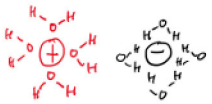
Major steps included:

- Determining the number of moles of both reactants
- Determining limiting reagent and moles of ester
- Determining mass of ester
- Determining experimental yield of ester

Question 28 (7 marks)

Ionic compounds can form saturated solutions in water.

(a) Explain the processes involved when an ionic compound dissolves in water. Use diagrams to support your explanation. 3



The polar H_2O molecules orientate themselves so the δ^- oxygen is attracted to the cation (ion-dipole force) and δ^+ H's are attracted to the ANION.

ENERGY IS NEEDED TO OVERCOME THE IONIC BONDS (LATTICE ENERGY)

ENERGY IS RELEASED WHEN THE IONS BECOME HYDRATED

If the energy released during hydration is greater than the needed lattice energy then the ionic substance dissolves

(b) Lead(II) sulfate is an ionic compound used in lead-acid batteries. Write the equilibrium expression, K_{sp}, for a saturated solution of lead(II) sulfate. 1

$K_{sp} = [Pb^{2+}][SO_4^{2-}]$

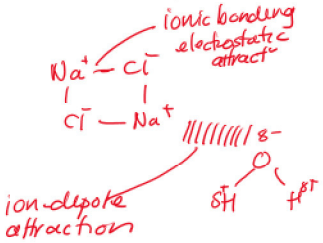
$Pb\ O_{(s)}$ $6+$ O_4^{2-}

Question 28 continues on page 25

24

Criteria (DLM)	Mark
Provides a detailed explanation of the process of dissolution and includes a relevant labelled diagram	3
Provides some explanation of the process of dissolution and a relevant diagram	2
Some relevant information	1

Marker comments: Very poorly done (and I mean very poorly done!). Students either knew the process or were clutching at straws. Many students incorrectly interpreted the question and gave irrelevant information about equilibrium in saturated solutions or reduced solubility in common ion solutions. This is definitely an area that students will need to revise prior to the HSC examinations.



Criteria (DLM)	Mark
Correct equilibrium expression	1

Marker comments: Very well done (yay!). A word of advice, if you have written the equilibrium equation before writing your K expression, put a line through the equation. Having both may indicate that you don't know which one is the correct answer.

Student Number

Question 28 (continued)

(c) Calculate the solubility of lead(II) sulfate at 25°C, in grams per 100 mL. 3

$PbSO_{4(s)} \rightleftharpoons Pb^{2+}_{(aq)} + SO_{4(aq)}^{2-}$

$K_{sp} = [Pb^{2+}][SO_4^{2-}]$ As $[Pb^{2+}] = [SO_4^{2-}] = x$

$2.53 \times 10^{-8} = x^2$

$x = \sqrt{2.53 \times 10^{-8}}$

$x = 1.59 \times 10^{-4}\ mol.L^{-1}$

$MM\ PbSO_4 = 207.2 + 32.07 + 64 = 303.27\ g/mol$

$M = n\,MM$

$M = (1.59 \times 10^{-4})(303.27)$

$M = 0.048219\ g$ in $1000\ mL$

$M = 0.00482\ g$ in $100\ mL$

$= 4.82 \times 10^{-3}\ g$ in $100\ mL$

End of Question 28

25

Criteria (DLM)	Mark
All 3 major steps correct	3
2 major steps correct	2
Some relevant information	1

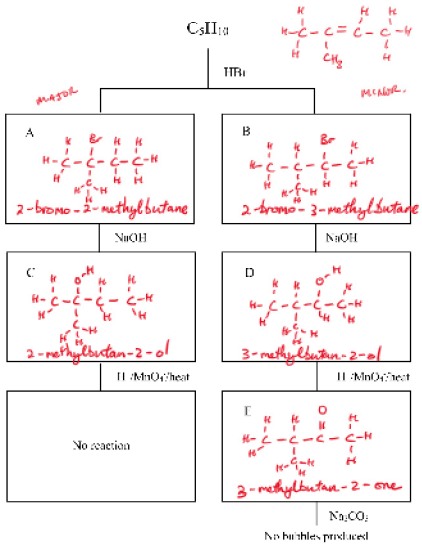
Marker comments: Generally well done. Most students were able to correctly determine the molar solubility of $PbSO_4$ and the number of moles (or mass) of $PbSO_4$ in 1L. A common error was multiplying by 10 instead of dividing by 10 to determine the mass in 100mL.

Major steps included:

- Determine the molar solubility of $PbSO_4$
- Determine the moles (or mass) of $PbSO_4$ in 1L
- Determine the mass of $PbSO_4$ in 100mL

Question 29 (5 marks)

Draw the structural formula and name each of the molecules A to E in the reaction sequence below. **5**



Criteria (KMT)	Marks
• Draws correct structural formulae for all five compounds	5
• Draws correct structural formulae for four compounds OR • Draws five correct structural formulae with one minor error	4
• Draws substantially correct structural formulae demonstrating an understanding of most reactions • 4-5 *substantially* correct structures (can be isomers of the correct structures) OR • 3 correct structures	3
• Draws structural formulae demonstrating an understanding of some different reactions • 2-3 *substantially* correct structures (can be isomers of the correct structures) OR • 2 correct structures	2
• Draws a substantially correct structural formula, linked to the correct reactions	1

Markers comments:

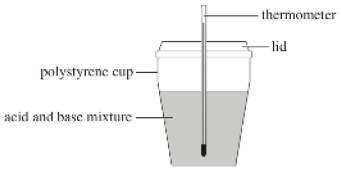
This was relatively well done. There were a spread of marks, about 20% got 5/5.

- The most common error was starting with a linear compound and ending up with a carboxylic acid at the end, or, starting with the branched compound which has the double bond at position 1 rather than position 2, giving a primary alcohol and hence an acid at the end. Both would receive a mark of 3/5.
- There were some minor errors such as H's missing, or bonds missing, which would have received a 4/5 if all other aspects were correct.

Student Number

Question 30 (9 marks)

A group of students conducted an experiment using the calorimeter shown to determine the heat of neutralisation for an acid/base reaction.



The students added 200.0 mL of 1.00 mol L^{-1} nitric acid (HNO_3) to 200.0 mL of 1.00 mol L^{-1} potassium hydroxide (KOH) and stirred the mixture. An initial temperature of 22.7°C and a final temperature of 26.4°C were recorded.

(a) Calculate the molar enthalpy of neutralisation between nitric acid and potassium hydroxide. **3**

$HNO_{3(aq)} + KOH_{(aq)} \rightarrow KNO_{3(aq)} + H_2O_{(l)}$

$n_{H_2O} = n_{HNO_3} = n_{KOH} = cV = (1.00)(200.0 \times 10^{-3}) = 0.2\ M$

$Q = mc\Delta T$

$Q = (400 \times 10^{-3})(4.18 \times 10^{3})(3.7)$ $\quad \Delta H = \frac{Q}{n}$

$Q = 6186.4\ J$ $\quad = \frac{6.1864\ kJ}{0.2\ mol}$

$Q = 6.1864\ kJ$

$= -30.9\ kJ.mol^{-1}$

Question 30 continues on page 28

Criteria (KMT)	Marks
• Correctly calculates the enthalpy of neutralisation • Includes all necessary steps	3
• Includes most steps OR • Correctly calculates the enthalpy of neutralisation, missing the negative sign, or units	2
• Provides some relevant information	1

Markers comments:

This was well done. The major difference between a 2 and 3 came down to one of these things:

- Not including units, and/or the negative sign
- Not including the step where the moles of water is calculated. It was not enough to calculate the moles of acid or base, as enthalpy of neutralisation is per mole of water, this step was required to get a mark of 3.

Question 30 (continued)

(b) The theoretical enthalpy of neutralisation of any strong acid and strong base is -57 kJ/mol.

Explain the effect of ONE source of error on the calculated enthalpy of neutralisation. 3

HEAT LOST TO THE SURROUNDINGS ∴ ΔT smaller than it should be, As Q = mcΔT, with ΔT ↓ the value for Q will also be smaller than it should be and ∴ as $\Delta H = \frac{Q}{n}$, then the value of ΔH will also be smaller than it should be.

(c) Describe an application of neutralisation reactions in everyday life. Include a balanced chemical equation in your answer. 3

Used as an antacid eg. magnesium hydroxide will relieve heartburn, indigestion as it reacts with and neutralises the excess stomach acid

$Mg(OH)_{2(aq)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + 2H_2O_{(l)}$

End of Question 30

Criteria (ETH)	Marks
• Identifies a valid source of error • Explains effect of error on deltaT value • Explain effect of deltaT value on deltaH value	3
• Missing one of the above	2
• Provides some relevant information	1

Markers comments:

Generally very well done. Most students were able to identify a valid source of error (most said heat loss to surroundings).

Students lost marks by not explaining (i.e. giving cause and effect) the effect of the heat loss on the calculation. Essentially, they did not read and answer the question in full.

Criteria (ETH)	Marks
• Identifies a relevant everyday life neutralisation reaction • Describes the application of this reaction • Correct and relevant chemical equation	3
• Missing one of the above	2
• Provides some relevant information	1

Markers comments:

This was not a well done question. Many students did not provide a relevant reaction, and many described an industrial reaction and not an everyday one.

Even when students did identify a relevant everyday reaction, they often did not describe its application and very often did not have a chemical equation to include.

Not many students obtained full marks for this question.

Student Number

Question 31 (4 marks)

Determine whether a precipitate will form when 50.0 mL of 0.052 M $Ba(OH)_2$ is mixed with 50.0 mL of 0.049 M Na_2SO_4. 4

$Ba(OH)_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2NaOH_{(aq)}$

$[Ba^{2+}]$ $C_1V_1 = C_2V_2$ $[SO_4^{2-}]$ $C_1V_1 = C_2V_2$

$(0.052)(50) = C_2 \times 100$ $(0.049)(50) = C_2 \times 100$

$[Ba^{2+}] = 0.026\,M$ $[SO_4^{2-}] = 0.0245\,M$

$BaSO_4 \rightleftharpoons Ba^{2+} + SO_4^{2-}$

$Q_{sp} = [Ba^{2+}][SO_4^{2-}]$

$Q_{sp} = (0.026)(0.0245)$ $K_{sp} = 1.08 \times 10^{-10}$

$Q_{sp} = 6.4 \times 10^{-4}$

As $K_{sp} < Q_{sp}$ a precipitate will form.

Criteria (ETH)	Marks
• Correctly determines whether a precipitate forms, including all relevant steps • Conc of ions • Qsp • Comparing Qsp with Ksp	4
• As above, but with one error • OR • As above, but with incorrect final conclusion	3
• Correct process but incorrect calculations and/or incorrect final conclusion	2
• Some relevant information	1

Markers Comments:

This question was generally well done.

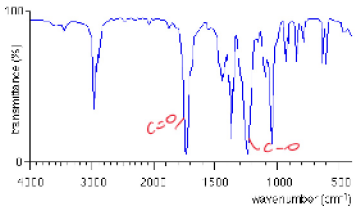
Common errors included:
- Calculating the concentration of BaSO4 and NaOH instead of Ba and SO4
- Incorrect equations, leading to incorrect conclusions
- Not using C1V1 = C2V2, leading to incorrect values

Question 32 (8 marks)

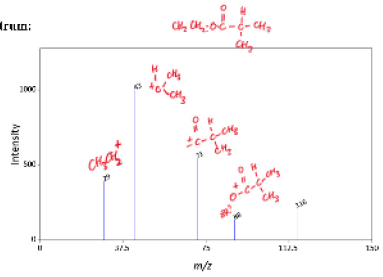
A range of analysis techniques were performed on a sample of a substance found in wine.
% composition analysis revealed C: 62.0%, H:10.4%, O:27.6%.

The spectra obtained from this analysis are presented below, along with ^{1}H NMR chemical shift data:

Infra-red:



Mass Spectrum:

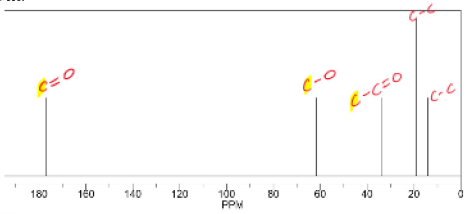


Question 32 continues on page 31

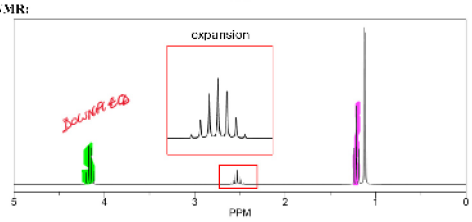
Student Number

Question 32 (continued)

^{13}C NMR:



^{1}H NMR:



Data from ^{1}H NMR spectrum

Chemical Shift	*Relative peak area*	*Splitting pattern*
1.1	6	doublet
1.2	3	triplet
2.6	1	septet
4.2	2	quartet

Question 32 continues on page 32

Question 32 (continued)

^{1}H NMR chemical shift data

Type of proton		δ/ppm
$Si(CH_3)_4$	(TMS)	0
R—CH_3		0.7–1.3
R—CH_2—R		1.2–1.5
R—CHR_2		1.5–2.0
H_3C—CO—	(aldehydes, ketones or esters)	2.0–2.5
—CH—CO—	(aldehydes, ketones or esters)	2.1–2.6
H_3C—O—	(alcohols or esters)	3.2–4.0
—CH—O—	(alcohols or esters)	3.3–5.1
R_2—CH_2—O—	(alcohols or esters)	3.5–5.0
R—OH		1–6
R_2C=CHR	(alkene)	4.5–7.0
R—CHO	(aldehyde)	9.4–10.0
R—COOH		9.0–13.0

(a) With reference to the percentage composition and the mass spectrum, determine the molecular formula of the compound. **1**

EF : C : H : O

62 : 10.4 : 27.6

12.01 : 1.008 : 16

5.16 : 10.317 : 1.725

5.16/1.725 : 10.317/1.725 : 1.725/1.725

3 : 6 : 1

EF is C_3H_6O

MM C_3H_6O = 58 g/mol

The actual molar mass from the mass spectrum is 116 g/mol

∴ molecular formula $C_6H_{12}C_2$

116/58 = 2

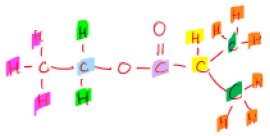
Markers comments (KMT): For one mark, it was necessary to reference the percentage composition and mass spec data. Some responses just provided the correct formula, which didn't receive the 1 mark. It is important to address the question, even for 1 mark.

Question 32 continues on page 33

Student Number

Question 32 (continued)

(b) Draw the structural formula of the compound and justify your decision by referring to data in all the spectra provided. **7**



C-13 NMR

5 CARBON ENVIRONMENTS. As there are 6 Cs in the molecule there must be some symmetry. A peak in 160-185 range indicating presence of carbon atom in carbonyl group. Peak in 50-90 range is C-O. Peak at 35 corresponding to C-C. Large peak at about 19 corresponding to the C-carbons in symmetrical methyl groups.

PROTON NMR

Quartet at 4.2 integrating for 2 H's and ∴ neighbour to 3 H's. Downfield so suggesting close to electronegative O- atom. and fitting data -CH_2-O 3.5-5.0

Triplet at 1.2 integrating for 3 H's and ∴ neighbour to 2 H's

Doublet at 1.4 integrating for 6 H's, ∴ neighbour has 1 H

Septet at 2.6 integrating for 1 H, ∴ split by neighbouring 6 H's

IR SPECTRUM

TROUGH at 1700 cm^{-1} ∴ C=O present

TROUGH at 1250 cm^{-1} ∴ C-O present

MASS SPECTRUM confirms

29 $CH_3CH_2^+$

43 $+C(CH_3)_2$

71 $+C(=O)-CH(CH_3)_2$

End of Question 32

Criteria (KMT)	Marks
• Writes the correct structural formula of the compound • Justifies the correct structure showing an extensive understanding of the interpretation of spectroscopic data • Refers explicitly to the relevant spectroscopic data	7
• Writes the correct structural formula for the correct compound OR an isomer of the correct compound • Justifies the structure showing a thorough understanding of the interpretation of spectroscopic data • Refers to relevant spectroscopic data	6
• Shows a sound understanding of the interpretation of spectroscopic data • Uses relevant information presented in the question to justify the structure of the chemical • Provides a structural formula consistent with analysis	4-5
Shows some understanding of the interpretation of spectroscopic data	2-3
Provides some relevant information	1

Markers comments:

This was pretty well done. There were only 10-15 7/7 and otherwise a range of marks.

- Many students figured out it was an ester, but some chose an isomer of the correct structure. With a thorough explanation of the data, an isomer may still have received 6/7.
- The most common issue was insufficient justification. The data needs to be explicitly referenced and the splitting pattern in the 1H NMR needs to be explained and linked to the proposed structure.
- The fragmentation in the mass spec was also not heavily referenced and this needs to be analysed to get 7/7.
- Some students had the correct structure but lacked justification and may have got a 4-5/7 as a result.

Question 33 (7 marks)

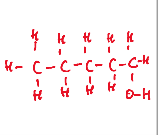
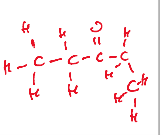
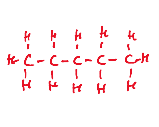
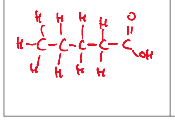
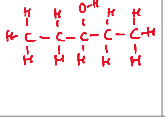
The labels and most of the information for five organic compounds in the laboratory store cupboard have been lost. The compounds are known to be pentane, pentan-1-ol, pentan-3-ol, pentan-3-one and pentanoic acid.

Use the clues below and the boiling point data in the table to identify the five compounds. Draw the structural formula of each compound (in the table below) and justify your identifications with reference to specific data, structural formulae and/or relevant chemical equations. 7

Clues

1. The C-NMR of B has three peaks.
2. The C-NMR of C has three peaks.
3. A forms D by reaction with acidified MnO_4^-.
4. E forms B by reaction with acidified MnO_4^-.

Compound	Boiling Point	
A	138°C	pentan-1-ol
B	102°C	pentan-3-one
C	36.1°C	Pentane
D	186°C	pentanoic acid
E	116°C	pentan-3-ol

A 	B 
C 	D 
E 	

Question 33 continues on page 35

Student Number

Question 33 (continued)

B and C are symmetrical molecules as only 3 carbon environments. As B is formed from E, with the addition of H^+/MnO_4^- E must be the pentan-3-ol and B the pentan-3-one.

A forms D when H^+/MnO_4^- is used making A the pentan-1-ol and D the pentanoic acid. This is confirmed by D having the highest bp. as the intermolecular forces in pentanoic acid would be the strongest, as they will be hydrogen bonds.

C is left, must be pentane. This is confirmed by lowest bp, as it only has dispersion forces to break; and by suggestion of symmetry with 3 peaks in NMR data.

→ ∴ will either be pentane or pentan-3-one.

End of Question 33

End of Paper

Criteria (ETH)	Marks
• All structures correctly identified and drawn in table • Correct, relevant, and logical justifications given for each structure	7
• All structures correctly identified and drawn in table • Correct, relevant, and logical justifications given for most structures	6
• All structures correctly identified and drawn in table • Correct justifications given, but the justifications are not robust or are not always logical conclusions	5
• All structures correctly identified and drawn in table • Justification absent or incorrect	4
• 3-4 structures correctly identified and drawn in table • Some relevant justifications present	3
• 1-2 structures correctly identified and drawn in table • Some relevant justifications present	2
• Some relevant information	1

Markers comments:

This was overall done well. A number of students obtained full marks, and there were some excellent answers.

Students who did well:
- Were able to correctly answer the question and the verb 'justify' --> they provided their own content knowledge to supplement the information given in the question to genuinely justify their choices
- Laid out their answer in a logical sequence (often using subheadings)
- Had neat and clear structural formula

Students who did not do well:
- Lacked justifications
  - Unfortunately, a number of students received 4 or 5 marks despite getting all the structural formula correct.
- Just repeated information from the question as their justification, but did not explain these any further with their own content knowledge
- Often did not reference relevant IMFs in their justifications