2020

JAMES RUSE AGRICULTURAL HIGH SCHOOL

TRIAL HSC EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A formula sheet, data sheet and Periodic Table are provided
- For questions in Section II, show all relevant working in questions involving calculations

Total Marks – 100

Section I – 20 marks (pages 2-10)

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

Section II – 80 marks (pages 11-30)

- Attempt questions 21-34
- 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
Mark your answers on the ANSWER grid in the Answer booklet on page 11.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

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 the correct answer by writing the word *correct* and drawing an arrow as follows.

correct

A ⊗ B ⊗ C ○ D ○

1. Which test tube represents the results when cyclohexene is shaken with bromine water?

A.  orange

B. 

C. 

D.  orange

2. When is equilibrium reached in a reversible reaction?

A. When molecules of reactants cease to change into molecules of products.

B. When the concentrations of reactants and products are equal.

C. When the concentrations of reactants and products are constant.

D. When the activation energy of the forward reaction is equal to that of the reverse reaction.

3. Which acid/base pair could act as a buffer?

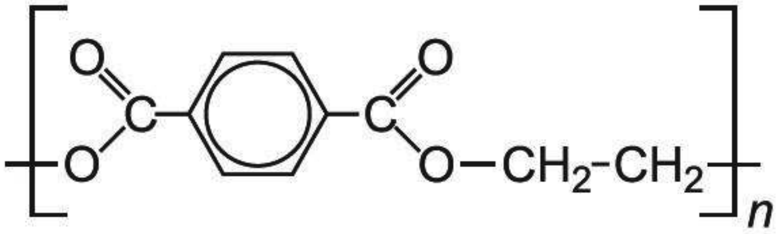
A. H_3O^+/H_2O

B. H_2O/OH^-

C. HNO_3/NO_3^-

D. $H_2PO_4^-/HPO_4^{2-}$

4. Consider the polymer represented by this structure.



Which alternative best describes the type of polymerisation and the name of the polymer?

A. condensation, polyester

B. addition, polyester

C. condensation, nylon

D. addition, nylon

5. Which colour is observed during the flame test of calcium ions?

A. Brick Red

B. Lilac

C. Green

D. Yellow

6. Which of the following are isomers?

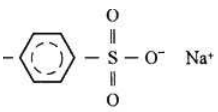
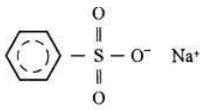
A. propanal and butanal

B. pentane and cyclopentane

C. methyl ethanoate and propanoic acid

D. butanone and butan-1-ol

7. Which formulae best represent a soap and a detergent?

	soap	*detergent*
A.	$C_{17}H_{35}COOH$	$C_{17}H_{35}COONa$
B.	$C_{17}H_{35}COONa$	$C_{17}H_{35}$ – 
C.	$C_{17}H_{35}$– 	$C_{17}H_{35}COONa$
D.	$C_{17}H_{35}COONa$	$C_{17}H_{35}COOCH_3$

8. What volume of gas would be produced when 45.0 g of glucose ($C_6H_{12}O_6$) is completely converted to ethanol and carbon dioxide at 40ºC and 110 kPa of pressure?

A. 0.756 L

B. 1.51 L

C. 5.91 L

D. 11.8 L

9. Which of the following chemical reagents could be used to identify the difference between primary, secondary, and tertiary alcohols?

A. Sodium metal

B. Zinc chloride with hydrochloric acid.

C. Acidified permanganate

D. Acidified dichromate

10. With which of the following conditions is a chemical reaction most likely to be spontaneous?

	Entropy is	*Enthalpy is*	*Gibbs free energy*
A.	decreasing	increasing	< 0
B.	increasing	decreasing	< 0
C.	increasing	increasing	> 0
D.	decreasing	decreasing	Not relevant

11. A student performed an experiment to investigate the barium content in a medical contrasting agent. Since the contrasting agents contain a variety of barium-compounds, gravimetric analysis techniques were employed.

An excess of sodium sulfate was added to the contrasting agent solution to precipitate all the barium ions as barium sulfate. Once all the precipitate had formed it was removed via filtration and dried.

How many grams of barium are in a sample of the contrasting agent if the solution of this sample gave 0.513 g of barium sulfate precipitate.

A. 0.032 g

B. 0.055 g

C. 0.269 g

D. 0.302 g

12. Which of the following chemical reagents would be most suitable for the gravimetric analysis of silver ions in a sample?

A. Ammonium chloride

B. Potassium sulfate

C. Barium carbonate

D. Sodium nitrate

13. Consider the following compounds.

Compound	*Formula*
W	CH_3COOCH_3
X	$CH_3CH_2NH_2$
Y	CH_3COOH
Z	C_2H_5OH

Which of the following best describes the nature of these compounds?

A. X and Z are both basic

B. W is acidic, and Z is basic

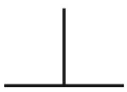
C. Y is acidic, and X is basic

D. W and Y are both acidic

14. A molecule of *N*-methylethanamine is shown.

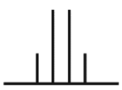
$$CH_3 - NH - CH_2 - CH_3$$

Which of the following shows the splitting pattern that would be observed for the labelled environment in the hydrogen NMR spectrum of this molecule?

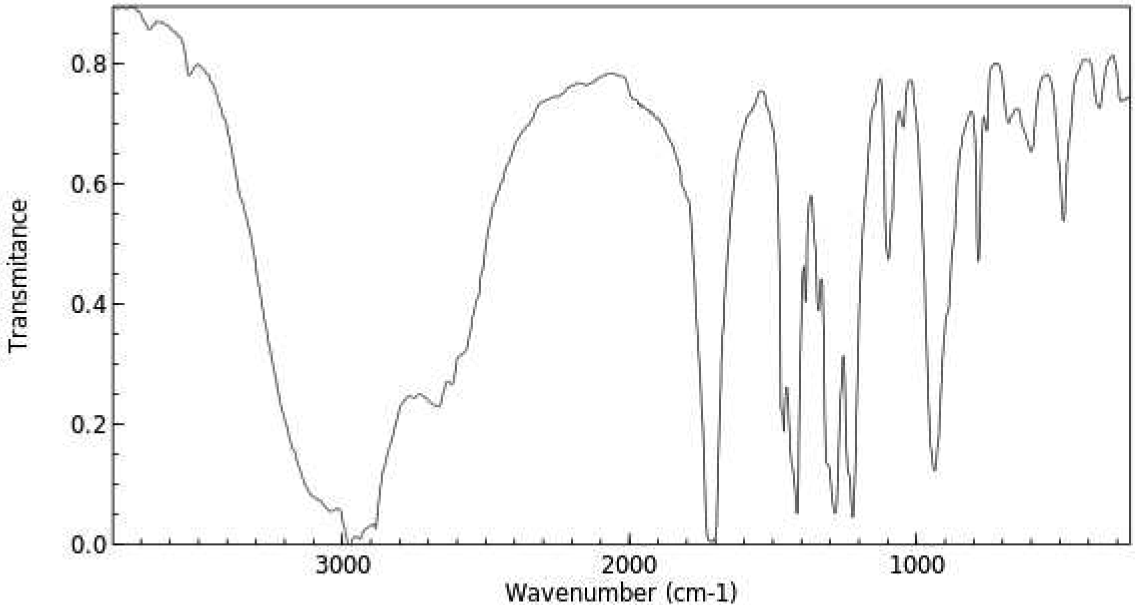
A. 

B. 

C. 

D. 

15. An infrared spectrum has been provided for an unknown organic compound.



Which class of compound is represented in this spectrum?

A. Ketone

B. Alcohol

C. Aldehyde

D. Carboxylic acid

16. A student added 50.00 mL of 0.350 mol L^{-1} hydrochloric acid to 50.00 mL of 0.025 mol L^{-1} barium hydroxide in a beaker.

What is the pH of the final solution?

A. 0.46

B. 0.79

C. 0.82

D. 1.79

17. The amount of dissolved oxygen in a water sample can be determined by utilising a sequence of reactions.

1. $2Mn^{2+}(aq) + O_2(g) + 4OH^-(aq) \rightarrow 2MnO(OH)_2(s)$

2. $MnO(OH)_2(s) + 2I^-(aq) + 4H^+(aq) \rightarrow I_2(aq) + Mn^{2+}(aq) + 3H_2O(aq)$

3. $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

A 2.5 L water sample was analysed using this process.
5.0×10^{-3} moles of iodide ions were produced in step 3.

What concentration of oxygen was present in the original sample?

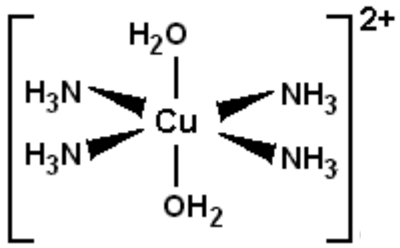
A. 8.0 mg L^{-1}

B. 16 mg L^{-1}

C. 32 mg L^{-1}

D. 64 mg L^{-1}

18. The structure of a complex ion is shown below.



SGS note: The dot point says that we must conduct qualitative investigations – using flame tests, precipitation and complexation reactions as appropriate – to test for the presence of ions in aqueous solution. We are not expected to understand how complexes form.

Which statement is correct for this ion?

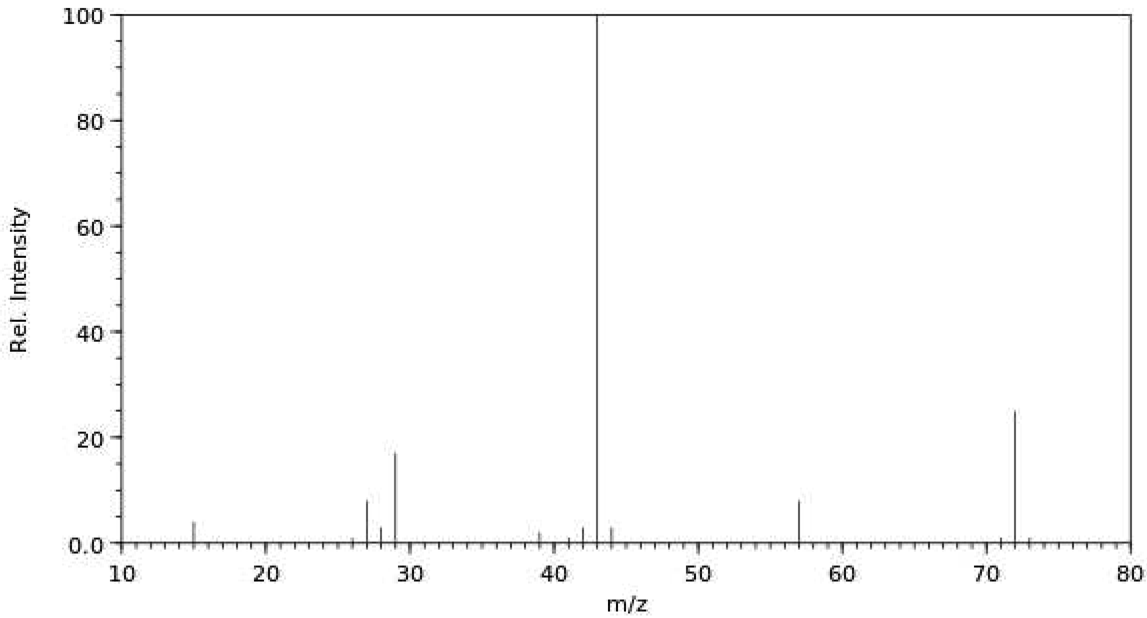
A. Water is the solvent that hydrogen bonds with the copper ion forming a ligand.

B. Ammonia is a ligand that donates an electron pair to the copper ion.

C. Water is a ligand that forms dipole-dipole attractions with the copper ion.

D. The final complex ion forms a ligand.

19. The fragmentation pattern of butanone is shown in the mass spectrum provided.



Which of the following is a possible fragment for the base peak?

A. $[CH_3]^+$

B. $[CH_3CH_2]^+$

C. $[CH_3CO]^+$

D. $[CH_3CH_2COCH_3]^+$

20. Which of the following combinations will produce the solution with the greatest temperature change?

	Acid	*Base*
A.	100 mL 0.1 mol L^{-1} H_2SO_4	50 mL 0.4 mol L^{-1} KOH
B.	50 mL 0.05 mol L^{-1} HNO_3	100 mL 0.4 mol L^{-1} NaOH
C.	50 mL 0.2 mol L^{-1} HCl	100 mL 0.025 mol L^{-1} $Ba(OH)_2$
D.	200 mL 0.05 mol L^{-1} CH_3COOH	50 mL 0.4 mol L^{-1} NaOH

JRAHS Chemistry Trial 2020 **Student Number** ……………………………

Mark……………………………………

Section I

Multiple Choice Answer Sheet

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

Section II - 80 marks

Attempt Questions 21 – 34

Allow about 2 hours and 25 minutes for this section

- Answer all 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 and direct the examiner to your answer.

Question 21 (6 marks)

When sulfur dioxide and oxygen react, the following equilibrium is established.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \qquad \Delta H = -197\text{ kJ mol}^{-1}$$

(a) Explain the conditions of temperature and pressure that will increase the yield in this reaction. **4**

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(b) Explain any effect on the equilibrium constant if the temperature is increased. **2**

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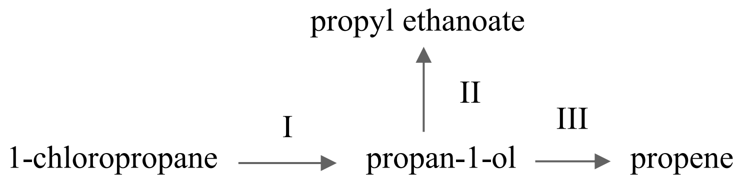
Question 22 (6 marks)

The following reaction scheme shows organic reactions, I, II and III.



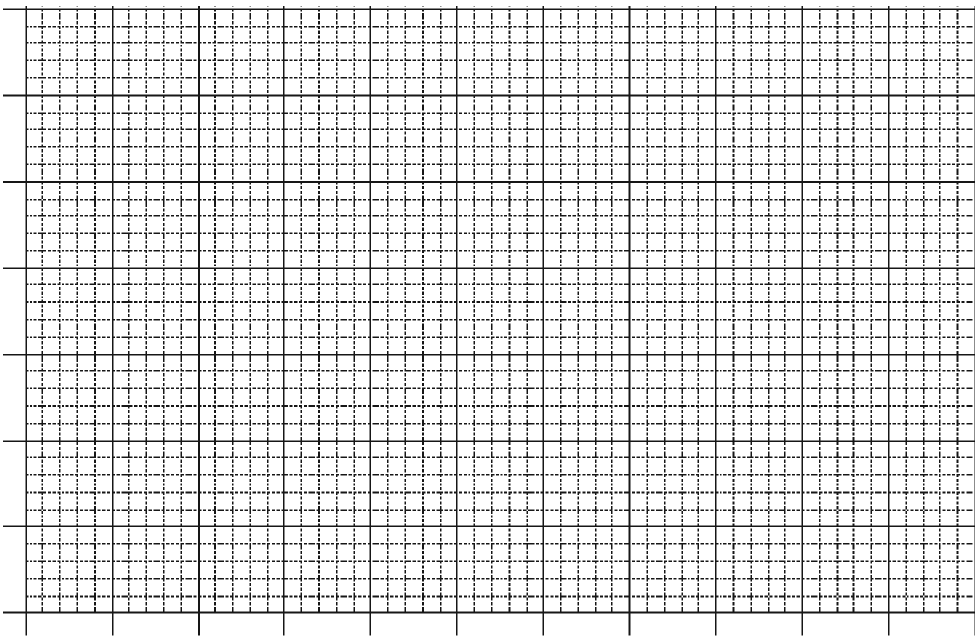
For each of the reactions (I, II and III), identify the type of reaction and the reagents and conditions required. **6**

Question 23 (6 marks)

The molar heats of combustion for three alcohols were determined.

Alcohol	*Heat released ($kJ\ mol^{-1}$)*
Ethanol	1200
Propan-1-ol	1900
Pentan-1-ol	3300

(a) Plot a graph of the molar heat of combustion versus molar mass for the three alcohols. **3**



Molar mass

(b) Use the graph to estimate the heat of combustion of butan-1-ol. **1**

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(c) Calculate the heat released when 20.0 g of ethanol undergoes complete combustion. **2**

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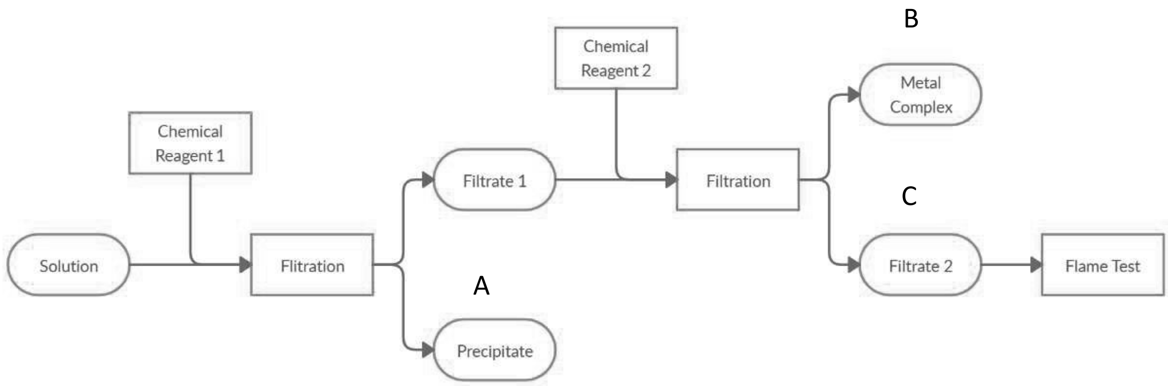
Question 24 (4 marks)

A solution contains a mixture of three cations, Ba^{2+}, Pb^{2+}, and Fe^{2+}. A student followed the sequence of steps outlined in the flowchart below to extract each of these cations separately.



This separation was achieved using only concentrated hydrochloric acid and a concentrated ammonia solution.

Identify each of the isolated products, A, B and C, and explain your reasoning using observations where appropriate. **4**

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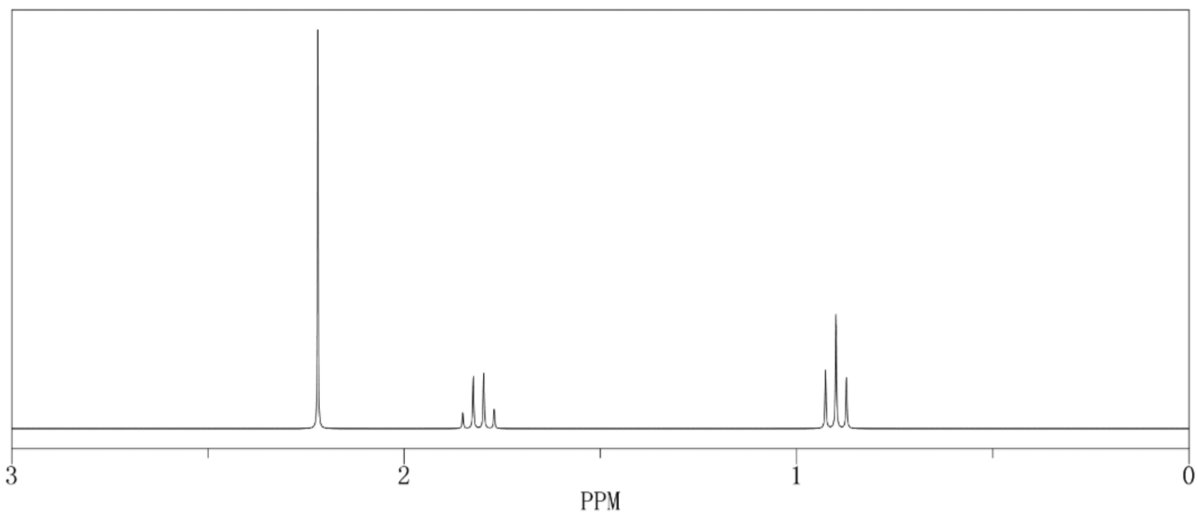
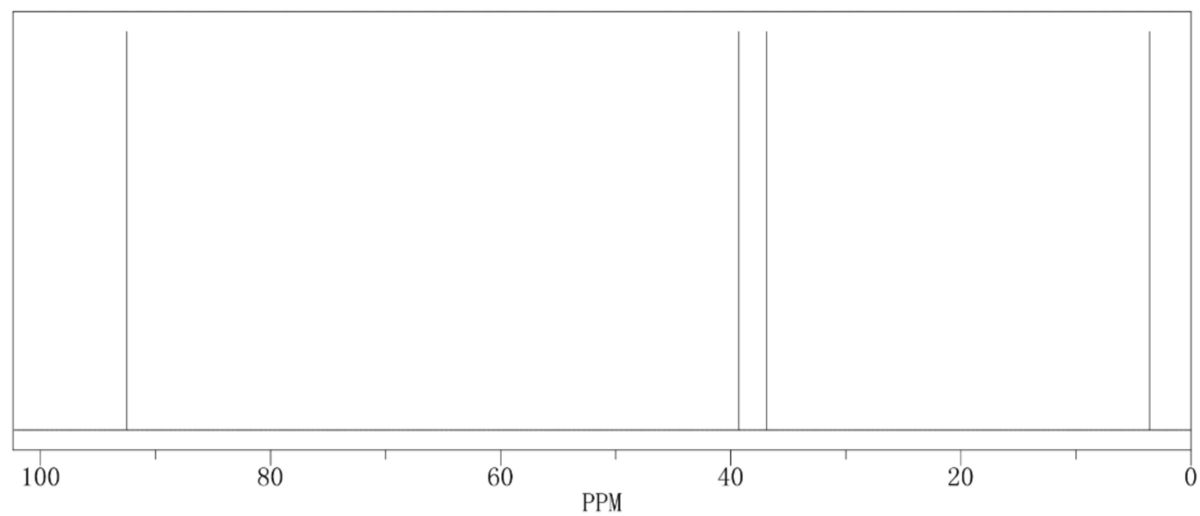
Question 25 (5 marks)

Chemists use a range of instrumental techniques to confirm which isomer of an organic compound is produced in a synthesis reaction. In one such instance a molecule with the formula $C_4H_8Cl_2$ was obtained. The chemist conducted mass spectroscopy and was able to use the fragmentation patterns to narrow down the possible isomers of this compound to either 2,2-dichlorobutane or 2,3-dichlorobutane. In order to confirm which of the two isomers was produced, they undertook NMR spectroscopy and obtained the following data.

^{1}H NMR spectrum



^{13}C NMR spectrum



Question 25 continues on page 17

Question 25 (continued)

(a) Draw the two isomers. **1**

2,2 dichlorobutane	*2,3 dichlorobutane*

(b) Justify which isomer was produced using the data provided and your predictions from the spectra of the isomer in terms of the number of peaks and the observed splitting patterns. **4**

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Question 26 (5 marks)

(a) Use Hess' Law and the heats of formation provided to calculate the enthalpy change for the reaction: **3**

$$2FeS_2(s) + 5O_2(g) \rightarrow 2FeO(s) + 4SO_2(g)$$

	$FeS_2(s)$	$O_2(g)$	$FeO(s)$	$SO_2(g)$
ΔH_f (kJ/mol)	-178	0	-272	-297

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(b) Explain any changes to the entropy as the reaction proceeds. **2**

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Question 27 (3 marks)

Chromate and dichromate ions establish the following equilibrium.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

The equilibrium constant for this reaction is 3×10^{14}.

What must the pH be so that the concentrations of chromate and dichromate ions are both 0.10 mol L^{-1}? **3**

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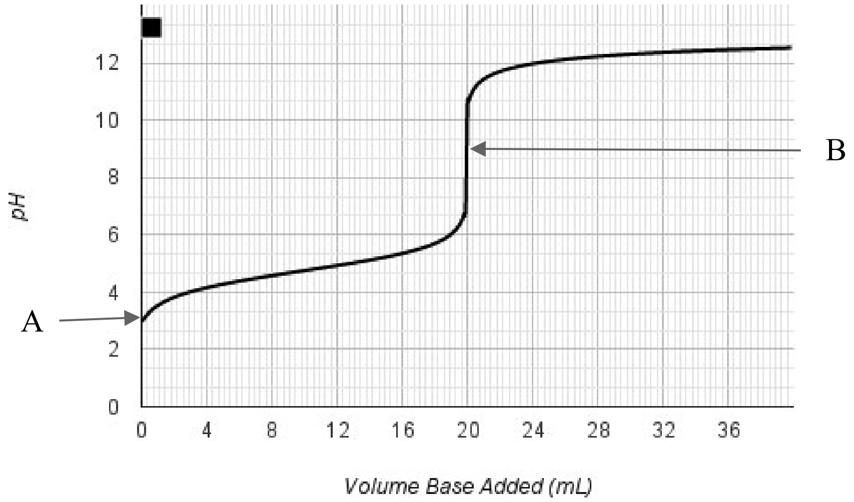
Question 28 (7 marks)

20.00 mL of 0.10 $molL^{-1}$ acetic acid solution in a conical flask was titrated with sodium hydroxide solution.

The results of the titration are shown in the graph.



(a) Identify a suitable indicator for the reaction **1**

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(b) Calculate and explain the concentration of hydrogen ions at positions A and B on the graph. Support your answer with TWO relevant equations. **6**

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Question 28 continues on page 21

Question 28 (continued)

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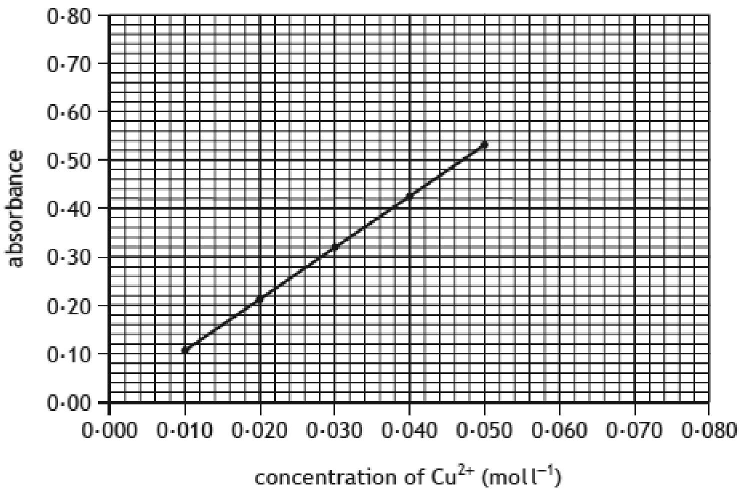
Question 29 (5 marks)

A student performed an experiment to determine the percentage of copper in a brass zipper. In order to do this the brass zipper was dissolved in 20 mL of concentrated nitric acid and the resulting solution was made up to 250 mL in a volumetric flask.

The student prepared five standard solutions by diluting a 0.10 mol L^{-1} stock solution of copper nitrate with deionised water. Each standard solution was analysed using an Atomic Absorption Spectrometer and the following calibration curve was obtained.



The sample was tested and an absorbance value of 0.72 was recorded. The student deemed this value incorrect and proceeded to dilute the sample to decrease its concentration by half.

(a) Explain why the sample solution was diluted. **2**

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The mass of the brass zipper was found to be 1.62 g and the absorbance was 0.36 when the sample concentration was halved.

(b) Calculate the percentage mass of copper in the brass zipper. **3**

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Question 30 (6 marks)

(a) Determine the solubility, in grams per millilitre, of sodium sulfate heptahydrate in distilled water, given its solubility product constant to be 17.67. **4**

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(b) Explain whether it is possible to completely dissolve 25 g of sodium sulfate heptahydrate in 100 mL of distilled water using the given solubility product constant in (a). **2**

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Question 31 (9 marks)

Three organic compounds, A, B and C, have the following properties.

	Organic compound	*Molar mass (g mol^{-1})*	*Boiling point ^{o}C*
A	Straight chain alkane	58	-1
B	Primary alcohol	60	97
C	Primary amide	59	210

(a) Use IUPAC nomenclature to identify compounds A, B and C **3**

A……………………………………………………………………………………………...

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B……………………………………………………………………………………………...

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C……………………………………………………… ………………………………..

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(b) Explain the different boiling points of compounds A, B and C. Use at least ONE labelled diagram to illustrate an explanation. **6**

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Question 31 continues on page 25

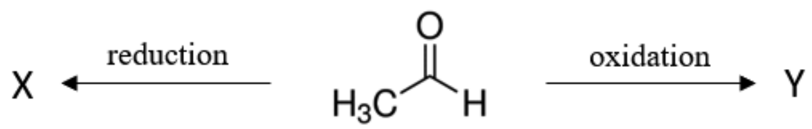
Question 31 (continued)

Question 32 (7 marks)

In organic chemistry, oxidation and reduction reactions occur as opposing reactions.

$$A \underset{\text{reduction}}{\overset{\text{oxidation}}{\rightleftharpoons}} B$$

The following reaction scheme can be used to synthesise two organic compounds from ethanal.



Identify the products X and Y and outline how the results of chemical tests and instrumental techniques (infrared and carbon NMR spectroscopy) could be used to confirm the identity of these compounds. 7

SGS note: The HSC specification does not state that we study reduction reactions of organic compounds. However, this question is valid.

Question 32 continues on page 27

Question 32 (continued)

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Question 33 (7 marks)

A manufacturer of a commercial brand of antacid claimed that each tablet had 99.9% magnesium carbonate. An analytical chemist followed the procedure described below to verify the manufacturer's claim.

1. A tablet was weighed then placed in a conical flask. The mass of the tablet was 0.747 g.

2. A bulb pipette was used to add 20.0 mL of 0.996 mol L^{-1} hydrochloric acid to the tablet in the conical flask.

3. After the reaction between the tablet and the hydrochloric acid had stopped, the mixture was gently boiled for 10 minutes. Then, 10.0 mL of demineralised water was added to the mixture in the conical flask.

4. Two drops of phenolphthalein indicator were added to the conical flask. This mixture was titrated with 0.110 mol L^{-1} of sodium hydroxide solution to neutralise the excess hydrochloric acid.

5. The average volume of sodium hydroxide solution required to change the colour of the indicator was 22.39 mL.

(a) Calculate the moles of acid in excess after the first reaction. **2**

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Question 33 continued on page 29

Question 33 (continued)

(b) Determine the percentage of magnesium carbonate in the antacid tablet and assess the accuracy of the manufacturer's claims. **5**

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Question 34 (4 marks)

A student prepared a solution consisting of 6.0 mol L^{-1} ammonium chloride and 0.40 mol L^{-1} ammonia.

(Assume complete dissociation of ammonium chloride in the solution)

At 25ºC : $Ka(NH_4^+) = 6.3 \times 10^{-10}$

(a) Write a net ionic equation for the reaction of ammonium chloride with water. **1**

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(b) Write the Ka expression for the reaction in (a). **1**

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(c) Calculate the pH of the prepared solution. **2**

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JRAHS Trial Chemistry Answers 2020

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

1. Which test tube represents the results when cyclohexene is shaken with bromine water?

A.

orange

B.

C.

D.

orange

2. When is equilibrium reached in a reversible reaction?

A. When molecules of reactants cease to change into molecules of products.

B. When the concentrations of reactants and products are equal.

C. When the concentrations of reactants and products are constant.

D. When the activation energy of the forward reaction is equal to that of the reverse reaction.

3. Which acid/base pair could act as a buffer?

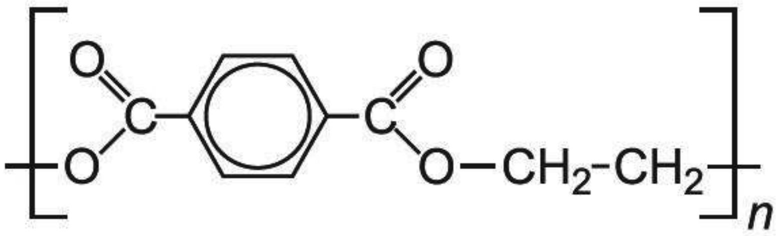
A. H_3O^+/H_2O

B. H_2O/OH^-

C. HNO_3/NO_3^-

D. $H_2PO_4^-/HPO_4^{2-}$

4. Consider the polymer represented by this structure.



Which alternative best describes the type of polymerisation and the name of the polymer?

A. condensation, polyester

B. addition, polyester

C. condensation, nylon

D. addition, nylon

5. Which colour is observed during the flame test of calcium ions?

A. Brick Red

B. Lilac

C. Green

D. Yellow

6. Which of the following are isomers?

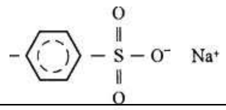
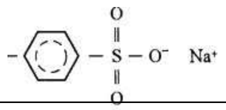
A. propanal and butanal

B. pentane and cyclopentane

C. methyl ethanoate and propanoic acid

D. butanone and butan-1-ol

7. Which formulae best represent a soap and a detergent?

	soap	*detergent*
A.	$C_{17}H_{35}COOH$	$C_{17}H_{35}COONa$
B.	**$C_{17}H_{35}COONa$**	**$C_{17}H_{35}$** 
C.	$C_{17}H_{35}$ 	$C_{17}H_{35}COONa$
D.	$C_{17}H_{35}COONa$	$C_{17}H_{35}COOCH_3$

8. What volume of gas would be produced when 45.0 g of glucose ($C_6H_{12}O_6$) is completely converted to ethanol and carbon dioxide at 40°C and 110 kPa of pressure?

A. 0.756 L

B. 1.51 L

C. 5.91 L

D. 11.8 L

9. Which of the following chemical reagents could be used to identify the difference between primary, secondary, and tertiary alcohols?

A. Sodium metal

B. Zinc chloride with hydrochloric acid.

C. Acidified permanganate

D. Acidified dichromate

10. With which of the following conditions is a chemical reaction most likely to be spontaneous?

	Entropy is	*Enthalpy is*	*Gibbs free energy*
A.	decreasing	increasing	< 0
B.	**increasing**	**decreasing**	**< 0**
C.	increasing	increasing	> 0
D.	decreasing	decreasing	Not relevant

11. A student performed an experiment to investigate the barium content in a medical contrasting agent. Since the contrasting agents contain a variety of barium-compounds, gravimetric analysis techniques were employed.

An excess of sodium sulfate was added to the contrasting agent solution to precipitate all the barium ions as barium sulfate. Once all the precipitate had formed it was removed via filtration and dried.

How many grams of barium are in a sample of the contrasting agent if the solution of this sample gave 0.513 g of barium sulfate precipitate.

A. 0.032 g

B. 0.055 g

C. 0.269 g

D. 0.302 g

12. Which of the following chemical reagents would be most suitable for the gravimetric analysis of silver ions in a sample?

A. Ammonium chloride

B. Sodium nitrate

C. Potassium sulfate

D. Barium carbonate

13. Consider the following compounds.

Compound	*Formula*
W	CH_3COOCH_3
X	$CH_3CH_2NH_2$
Y	CH_3COOH
Z	C_2H_5OH

Which of the following best describes the nature of these compounds?

A. X and Z are both basic

B. W is acidic, and Z is basic

C. Y is acidic, and X is basic

D. W and Y are both acidic

14. A molecule of *N*-methylethanamine is shown.

$$CH_3 - NH - CH_2 - CH_3$$

Which of the following shows the splitting pattern that would be observed for the labelled environment in the hydrogen NMR spectrum of this molecule?

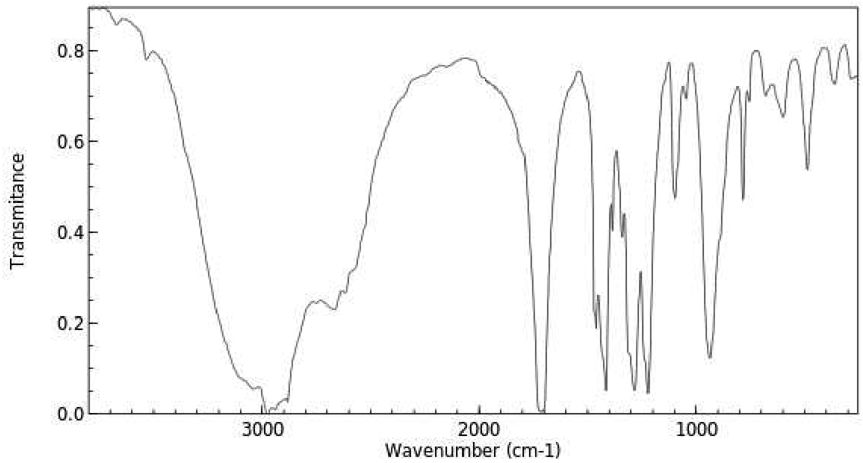
A. 

B. 

C. 

D. 

15. An infrared spectrum has been provided for an unknown organic compound.



Which class of compound is represented in this spectrum?

A. Ketone

B. Alcohol

C. Aldehyde

D. Carboxylic acid

16. A student added 50.00 mL of 0.350 mol L^{-1} hydrochloric acid to 50.00 mL of 0.025 mol L^{-1} barium hydroxide in a beaker.

What is the pH of the final solution?

A. 0.46

B. 0.79

C. 0.82

D. 1.79

17. The amount of dissolved oxygen in a water sample can be determined by utilising a sequence of reactions.

1. $2Mn^{2+}(aq) + O_2(g) + 4OH^-(aq) \rightarrow 2MnO(OH)_2(s)$

2. $MnO(OH)_2(s) + 2I^-(aq) + 4H^+(aq) \rightarrow I_2(aq) + Mn^{2+}(aq) + 3H_2O(aq)$

3. $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

A 2.5 L water sample was analysed using this process.
5.0×10^{-3} moles of iodide ions were produced in step 3.

What concentration of oxygen was present in the original sample?

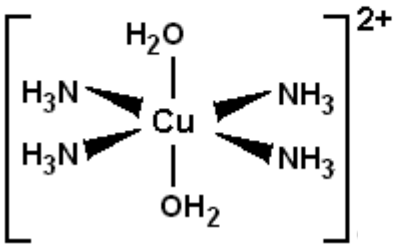
A. 8.0 mg L^{-1}

B. 16 mg L^{-1}

C. 32 mg L^{-1}

D. 64 mg L^{-1}

18. The structure of a complex ion is shown below.



Which statement is correct for this ion?

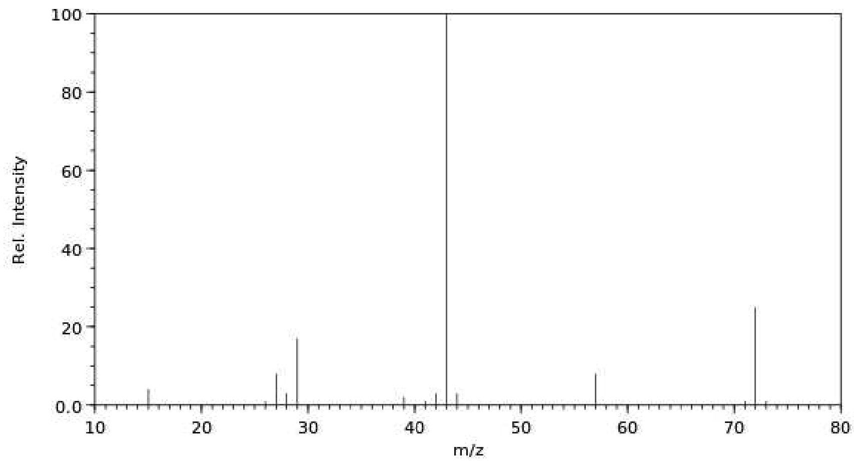
A. Water is the solvent that hydrogen bonds with the copper ion forming a ligand.

B. Ammonia is a ligand that donates an electron pair to the copper ion.

C. Water is a ligand that forms dipole-dipole attractions with the copper ion.

D. The final complex ion forms a ligand.

19. The fragmentation pattern of butanone is shown in the mass spectrum provided.



Which of the following is a possible fragment for the base peak?

A. $[CH_3]^+$

B. $[CH_3CH_2]^+$

C. $[CH_3CO]^+$

D. $[CH_3CH_2COCH_3]^+$

20. Which of the following combinations will produce the solution with the greatest temperature change?

	Acid	*Base*
A.	**100 mL 0.1 mol L^{-1} H_2SO_4**	**50 mL 0.4 mol L^{-1} KOH**
B.	50 mL 0.05 mol L^{-1} HNO_3	100 mL 0.4 mol L^{-1} NaOH
C.	50 mL 0.2 mol L^{-1} HCl	100 mL 0.025 mol L^{-1} $Ba(OH)_2$
D.	200 mL 0.05 mol L^{-1} CH_3COOH	50 mL 0.4 mol L^{-1} NaOH

Question 21 (6 marks)

When sulfur dioxide and oxygen react, the following equilibrium is established.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \qquad \Delta H = -197 \text{ kJ mol}^{-1}$$

(a) Explain the conditions of temperature and pressure that will increase the yield in this reaction. **4**

Sample answer: The reaction is exothermic. By Le Chatelier's principle equilibrium will shift to oppose a change to the system. By lowering the temperature, the reaction will shift to the side that opposes that change, that is, the one that produces heat. This is the forward reaction and equilibrium will shift to the right and increase the yield of sulfur trioxide.

There are 3 mole of gas on the reactants side and only 2 on the products side, Therefore, by increasing the pressure (high pressure), equilibrium will shift to the side that does the opposite i.e, lowers the pressure. The reaction that lowers the pressure is the one with fewer gas molecules, the forward reaction 3:2, increasing the yield of sulfur trioxide.

SGS note: Explaining shifts in equilibrium position usually requires an explanation involving collision theory. Le Chatelier's principle only predicts shifts in position.

Marking Criteria	*Mark(s)*
• Explains both conditions of temperature and pressure that will increase the yield of sulfur trioxide in terms of Le Chatelier's Principle.	4
• Explains the condition of temperature OR pressure that will increase the yield of sulfur trioxide in terms of Le Chatelier's Principle. AND • Outlines the other condition	3
• Outlines the conditions of temperature and pressure required to increase yield OR • Explains the condition of temperature OR pressure that will increase the yield of sulfur trioxide in terms of Le Chatelier's Principle.	2
• Gives some relevant information	1

(b) Explain any effect on the equilibrium constant if the temperature is increased. **2**

The equilibrium constant expression for the reaction is $K = [SO_3]^2 / [SO_2]^2[O_2]$

If temperature is increased, it favours the endothermic reverse reaction. There will be more reactants and therefore the equilibrium constant will decrease as seen in the expression

Marking Criteria	*Mark(s)*
• Gives the equilibrium constant expression AND • Explains the effect on the equilibrium constant	2
• Gives some relevant information	1

Question 22 (6 marks)

The following reaction scheme shows organic reactions, I, II and III.

propyl ethanoate $\xleftarrow{\text{II}}$ propan-1-ol

1-chloropropane $\xrightarrow{\text{I}}$ propan-1-ol $\xrightarrow{\text{III}}$ propene

For each of the reactions (I, II and III), identify the type of reaction and the reagents and conditions required.

Sample answer **6**

Reaction I is a substitution reaction. Water or metal hydroxide (NaOH, KOH) is reacted with the haloalkane. An hydroxyl group from water is substituted for the chlorine. ***SGS note: Only secondary and tertiary halogenoalkanes undergo substitution reactions with water, but 'water' was accepted on last year's HSC paper.***

Reaction II is esterification. Propan-1-ol is reacted with ethanoic acid and a concentrated sulfuric acid catalyst to produce the ester propyl ethanoate. ***SGS note: Also, reflux.***

Reaction III is dehydration of an alcohol to an alkene. Water is removed from the alcohol making an unsaturated alkene using a concentrated sulfuric acid catalyst. ***SGS note: Heat is also required for all elimination/dehydration reactions.***

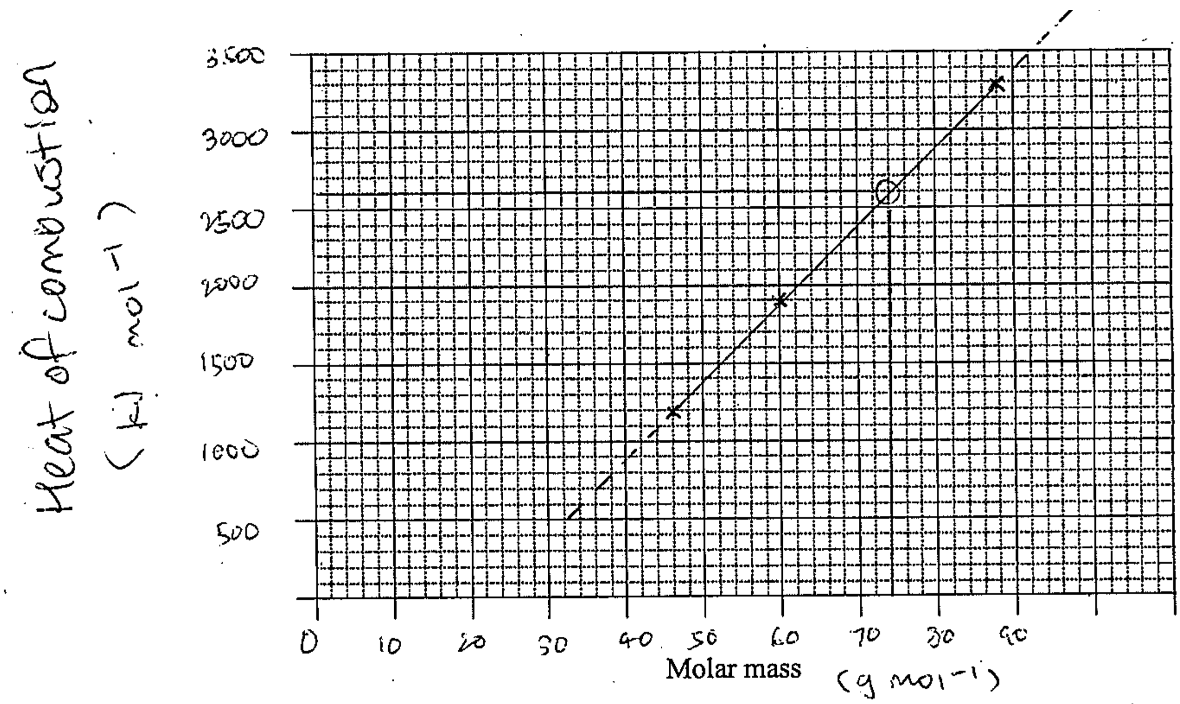
Marking Criteria	*Mark(s)*
• Correctly outlines the type of reaction, reagents and conditions for reactions I, II and III	6
• Outlines most of the required information for the 3 reactions	5
• Outline most of the reactions, reagents and conditions for two reactions	4
• Outlines some of the reaction reagents and conditions	3
• Gives some relevant information for one of the reactions	2
• Gives some relevant information	1

Question 23 (6 marks)

The molar heats of combustion for three alcohols were determined.

Alcohol	*Heat released (kJ mol⁻¹)*
Ethanol	1200
Propan-1-ol	1900
Pentan-1-ol	3300

(a) Plot a graph of the molar heat of combustion versus molar mass for the three alcohols. **3**



Marking Criteria	*Mark(s)*
• Correctly graphs results (uses an appropriate scale, labels axes correctly with units, accurately plots points, and draws a line of best fit).	3
• Provides a substantially correct graph	2
• Provides some basic features of the graph	1

(b) Use the graph to estimate the heat of combustion of butan-1-ol. **1**

2600 kJ mol^{-1}

Marking Criteria	*Mark(s)*
• Correctly estimates heat of combustion from the graph	1

(c) Calculate the heat released when 20.0 g of ethanol undergoes complete combustion. **2**

n $C_2H_5OH = m/MM = 20.0 / (2 \times (12.01) + 6 \times (1.008) + 16) = 0.434$ *mol*

1 mol C_2H_5OH *releases 1200 kJ*

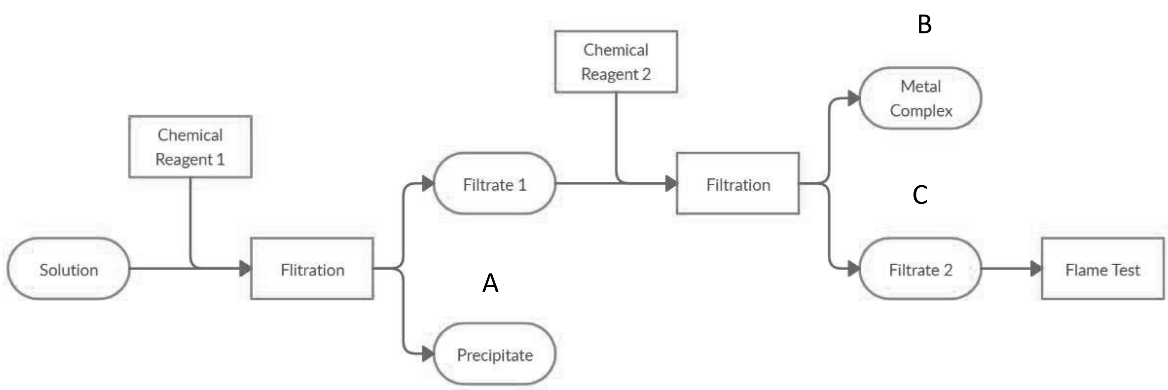
0.434 mol releases 1200 x 0.434 = 521 kJ

SGS note: Always state MM in your calculation

Marking Criteria	*Mark(s)*
• Correctly calculates the heat released showing all relevant working	2
• Shows some working	1

Question 24 (4 marks)

A solution contains a mixture of three cations, Ba^{2+}, Pb^{2+}, and Fe^{2+}. A student followed the sequence of steps outlined in the flowchart below to extract each of these cations separately.



This separation was achieved using only concentrated hydrochloric acid and a concentrated ammonia solution.

Identify each of the isolated products, A, B, and C, and explain your reasoning using observations where appropriate.

Sample answer:

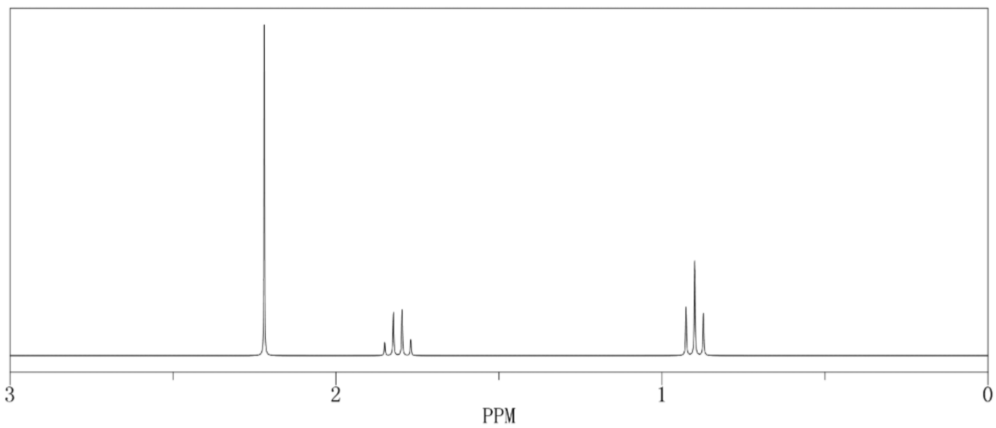
The first chemical reagent results in the production of a precipitate. As all ammonium salts are soluble, then chemical reagent 1 must be hydrochloric acid, which makes chemical reagent 2 ammonia. The first product is a precipitate of lead chloride, which is formed by exposing the initial solution to concentrated hydrochloric acid. This is the only possible product that could form from this chemical reagent since chloride salts of iron and barium are soluble. The second product is a metal complex made of iron. Of the remaining metal cations in solution, iron is the only one that is a transition that will form a green coloured insoluble metal complex when exposed to concentrated ammonia solution. The leftover filtrate contains the final product, barium ions, which are confirmed through flame testing by the presence of an apple green flame colour.

Marking Criteria	*Mark(s)*
• Correctly identifies the three products provides an explanation for the identification of each	4
• Correctly identifies at least two products and provides an explanation for the identification of at least two of them.	3
• Correctly identifies at least two products **OR** • Explains the identification of one product	2

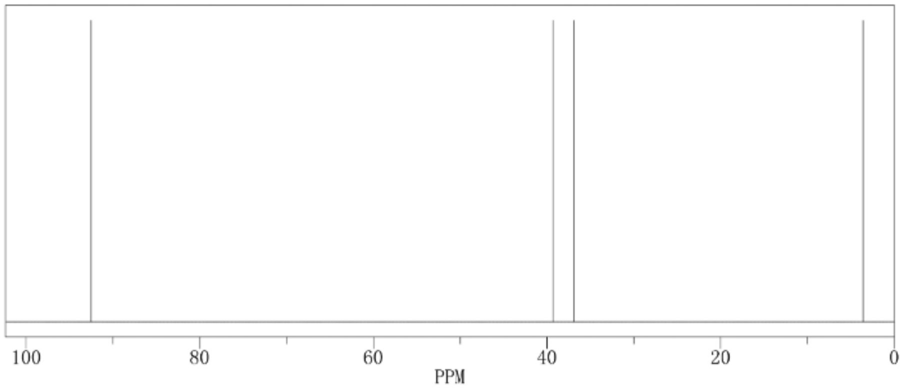
Question 25 (4 marks)

Chemists use a range of instrumental techniques to confirm which isomer of an organic compound is produced in a synthesis reaction. In one such instance a molecule with the formula $C_4H_8Cl_2$ was obtained. The chemist conducted mass spectroscopy and was able to use the fragmentation patterns to narrow down the possible isomers of this compound to either 2,2-dichlorobutane or 2,3-dichlorobutane. In order to confirm which of the two isomers was the product they undertook NMR spectroscopy and obtained the following data.

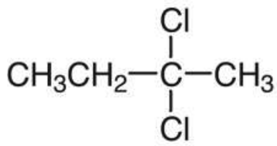
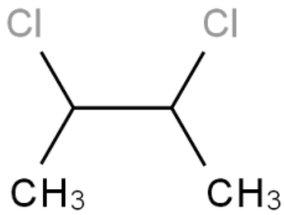
^{1}H NMR spectrum



^{13}C NMR spectrum



(a) Draw the two isomers. **1**

2,2 dichlorobutane	*2,3 dichlorobutane*
	

(b) Justify which isomer was produced using the data provided and your predictions from the spectra of the isomer in terms of the number of peaks and the observed splitting patterns. **4**

Sample answer:

Starting with the ^{1}H NMR spectrum provided, we can see three distinct signals are present in the product, which include a singlet, a triplet, and a quartet, representative of three distinct hydrogen environments. When we examine the structures of the two possible products, we can see that 2,3-dichlorobutane has a plane of symmetry, which would result in only two distinct hydrogen environments, which would be a multiplet and a doublet. This does not agree with the results here so the product must be 2,2-dichlorobutane with the singlet representing the isolated CH_3 group and the quartet and triplet representing the coupled CH_2CH_3 group. The same plane of symmetry also plays an important role in ^{13}C NMR, where we can see four distinct signals are present. This spectrum would is in agreement with the 2,2-dichlorobutane product, with the three carbon signals below 40 ppm representative of standard alkyl environments, albeit the two signals that are more downfield shifted are due to their proximity with the highly electronegative chlorine atoms. The heavily downfield shifted signal at 95 ppm corresponds to the carbon environment that has two chlorine atoms directly attached to it. This would differ from the spectra of the 2,3-dichlorobutane product which would only have two signals present, with one downfield shifted to roughly 70 ppm due to the presence of the chlorine atom attached. Thus, we can conclude that the product must be 2,2-dichlorobutane.

Marking Criteria	*Mark(s)*
• Gives correct justification for the product using hydrogen and carbon NMR spectroscopy. • References and explains number of signals in both products, splitting pattern for hydrogen NMR, and chemical shift for carbon NMR or explains and shows symmetry.	4
• Gives substantially correct justification for the product using hydrogen and carbon NMR spectroscopy. • References number of signals in one product, splitting pattern for hydrogen NMR, and / or chemical shift for carbon NMR.	3
• Gives substantially correct justification for the product using hydrogen or carbon NMR spectroscopy. OR • Outlines some features of both hydrogen and carbon NMR spectroscopy OR • Gives substantially correct analyses with incorrect structure.	2
• Provides some relevant information.	1

Question 26 (6 marks)

(a) Use Hess' Law and the heats of formation provided to calculate the enthalpy change for the reaction: **3**

$$2FeS_2(s) + 5O_2(g) \rightarrow 2FeO(s) + 4SO_2(g)$$

	$FeS_2(s)$	$O_2(g)$	$FeO(s)$	$SO_2(g)$
ΔH_f (kJ/mol)	-178	0	-272	-297

ΔH *reaction* = È ΔH_f *(products)* - ΔH_f *reactants*

= (2(-178) + 0) - (2(-272) + 4(-297)) = -1376 kJ

Marking Criteria	*Mark(s)*
• Correct calculation and sign for *ΔH*	3
• Most calculations correct	2
• Some correct calculation	1

(b) Explain any changes to the entropy as the reaction proceeds. **2**

Sample answer

As the reaction proceeds the number of gas molecules decreases (5:4), lowering the randomness of the system and lowering the entropy

Marking Criteria	*Mark(s)*
• Explains the lowering of entropy giving the ratio of gas molecules in the reaction	2
• Gives some relevant information	1

Question 27 (4 marks)

Chromate and dichromate ions establish the following equilibrium.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

The equilibrium constant for this reaction is 3×10^{14}.

What must the pH be so that the concentrations of chromate and dichromate ions are both 0.10 mol L^{-1}? **3**

$[Cr_2O_7^{2-}] = [Cr_2O_4^{2+}] = 0.10$

$K = 3 \times 10^{14} = [Cr_2O_7^{2-}] / [Cr_2O_4^{2+}]^2 [H^+]^2$

$3 \times 10^{14} = 0.10/0.10^2 \times [H^+]^2$

$[H^+]^2 = 1/ 3 \times 10^{14} \times 0.10$

$[H^+] = 1.826 \times 10^{-7}$

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

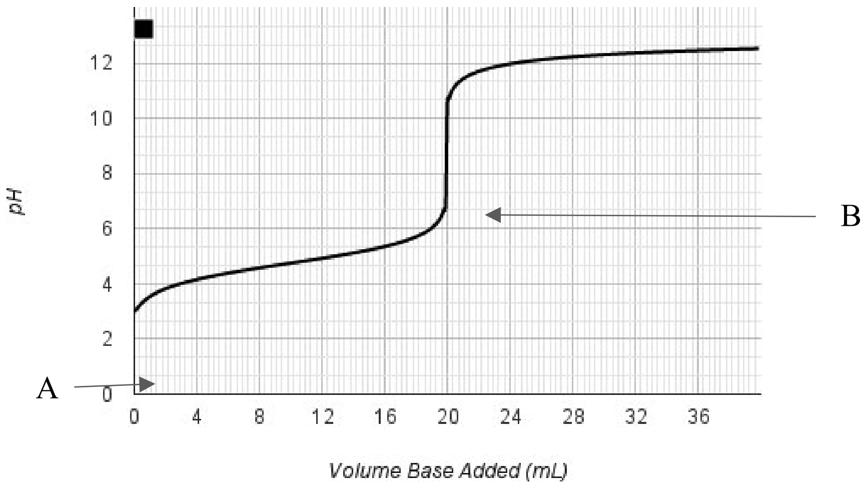
$= -\log 1.826 \times 10^{-7} = 6.74$

Marking Criteria	*Mark(s)*
• Correct K expression • Correct calculation showing all relevant working	3
• Correct calculation showing most relevant working	2
• Some calculation shown	1

Question 28 (7 marks)

20.00 mL of 0.10 molL^{-1} acetic acid solution in a conical flask was titrated with sodium hydroxide solution.

The results of the titration are shown in the graph.



(a) Identify a suitable indicator for the reaction *Phenolpthalein*

SGS note: The spec does not state that you learn indicators that can be used across specific pH ranges. However, as you have conducted titrations to determine pH, this question is valid. ***1***

(b) Calculate and explain the concentration of hydrogen ions at positions A and B on the graph. Support your answer with TWO relevant equations. **6**

Sample answer

pH at A = 3 *pH at B = 9*

[H$^+$] at A = 10^{-3} mol L^{-1} *[H$^+$] at A = 10^{-9} mol L^{-1}*

Position A gives the pH for the acetic acid solution. Acetic acid is a weak acid so even though it's concentration is 0.1 mol L^{-1}, it doesn't completely ionise in water and is in equilibrium with its ions. Therefore, the concentration of hydrogen ions is 10^{-3} molL^{-1}, much less than the acid concentration of 10^{-1} mol L^{-1}

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

At position B, the resultant solution of the reaction between a weak acid and a strong base is a basic salt, sodium acetate.

The acetate ion reacts with water to produce intact molecules of acetic acid and hydroxide ions and so the concentration of hydrogen ions is not 10^{-7} mol L^{-1} for a neutral solution but 10^{-9} mol L^{-1}, in a final basic solution.

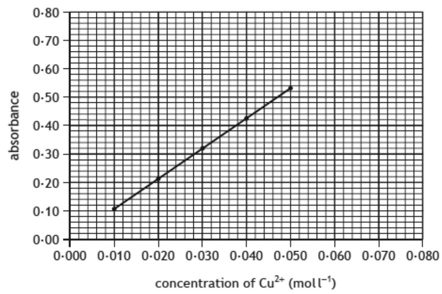
$$CH_3COO^-(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$$

Marking Criteria	*Mark(s)*
• Correctly calculates $[H^+]$ at A and B • Explains the $[H^+]$ at both A and B • Gives two correct equations that support the explanation of the concentrations at A and B	6
• Correctly calculates $[H^+]$ at A and B • Explains the $[H^+]$ at both A and B • Gives one correct equation that supports the explanation of the concentrations at A or B	5
• Correctly calculates $[H^+]$ at A or B • Outlines the $[H^+]$ at both A and B • Gives one mostly correct equation that explains the concentrations at A or B. OR • Correctly calculates $[H^+]$ at A or B • Explains the $[H^+]$ at A or B • Gives one mostly correct equation that explains the concentrations at A or B.	4
• Does some calculation AND • Outlines the $[H^+]$ at A or B OR • Gives one mostly correct equation that explains the concentrations at A or B. AND • Correctly calculates $[H^+]$ at A and B OR • Gives one mostly correct equation that explains the concentrations at A or B. AND • Explains the $[H^+]$ at A or B (no calculation)	3
• Outlines the $[H^+]$ at A or B OR • Correctly calculates $[H^+]$ at A and B OR • Does some calculation and gives a relevant equation	2
• Gives some relevant information	1

Question 29 (5 marks)

A student performed an experiment to determine the percentage of copper in a brass zipper. In order to do this the brass zipper was dissolved in 20 mL of concentrated nitric acid and the resulting solution was made up to 250 mL in a volumetric flask.

The student prepared five standard solutions by diluting a 0.10 mol L^{-1} stock solution of copper nitrate with deionised water. Each standard solution was analysed using an Atomic Absorption Spectrometer and the following calibration curve was obtained.



The sample was tested and an absorbance value of 0.72 was recorded. The student deemed this value incorrect and proceeded to dilute the sample to decrease its concentration by half.

(a) Explain why the sample solution was diluted. **2**

Sample answer: *Since the sample value recorded lies outside the data range of the calibration curve, it would be invalid to use this measurement. As a result, the concentration of the sample solution was diluted by half as a means to obtain a value within the data range of the calibration curve.*

Marking Criteria	*Mark(s)*
• Explains rationale for dilution with reference to validity.	2
• Provides some relevant information.	1

The mass of the brass zipper was found to be 1.62 g and the absorbance was 0.36 when the sample concentration was halved.

(b) Calculate the percentage mass of copper in the brass zipper. **3**

Sample answer:

Abs (sample) = 0.72 / 2 = 0.36 ∴ $[Cu^{2+}]$ (sample) = 0.034 mol L^{-1}

n (sample) = c x v = 0.034 x 2 x 0.25 = 0.017 mol

m (sample) = n x MM = 0.017 x 63.55 = 1.08 g

% mass (copper) = 1.08 / 1.62 x 100 = 67 %

Marking Criteria	*Mark(s)*
• Calculates the % mass of copper in brass showing all working.	3
• Provides substantially correct working.	2
• Provides some relevant information.	1

Question 30 (6 marks)

(a) Determine the solubility, in grams per millilitre, of sodium sulfate heptahydrate in distilled water, given its solubility product constant to be 17.67. **4**

$$Na_2SO_4.7H_2O\ (s) \rightleftharpoons 2Na^+\ (aq) + SO_4^{2-}\ (aq) + 7H_2O\ (l)$$

$K_{sp} = [Na^+]^2 \times [SO_4^{2-}]$

$= [2x]^2 \times [x]$

$= 4x^3$

$\therefore x^3 = 17.67$ $\quad x = 1.64\ M$ $\quad M(Na_2SO_4.7H_2O) = 268.152\ g\ mol^{-1}$

$[Na_2SO_4.7H_2O] = 1.64 \times [2(22.99 + 32.06 + 11(16.00) + 14(1.008)] / 1000 = 0.4400\ g/mL$

Marking Criteria	*Mark(s)*
• Provided the K_{sp} expression. • Calculated the concentration of the sulfate ion. • Expressed the solubility of sodium sulfate heptahydrate in grams per millilitre. • Correct significant figures	4
• Provided the K_{sp} expression. • Calculated the concentration of the sulfate ion. • Partially converted the solubility of of sodium sulfate heptahydrate to grams per millilitre.	3
• Provided the K_{sp} expression. • Calculated the concentration of the sulfate ion.	2
• Provided some relevant working	1

(b) Explain whether it is possible to completely dissolve 25 g of sodium sulfate heptahydrate in 100 mL of distilled water using the given solubility product constant in (a). **2**

It would be possible to dissolve 25 g of the solid in 100 mL of distilled water because it is less than the maximum amount of 44.00 g/100 mL. or K_{sp} is a large number.

If the calculated Q_{sp} is greater than the K_{sp}, the solution is saturated hence no more solute will dissolve.

Marking Criteria	*Mark(s)*
• Explained why dissolving 25 g is possible. • Related to the solubility product constant.	2
• Explained why dissolving 25 g is possible.	1

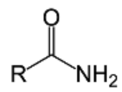
Question 31 (9 marks)

Marking Criteria	*Mark(s)*
• Correct calculation for $[H^+]$ showing all calculations	2
• Some correct calculation	1

Three organic compounds, A, B and C, have the following properties.

	Organic compound	*Molar mass (g mol^{-1})*	*Boiling point ^oC*
A	Straight chain alkane	58	-1
B	Primary alcohol	60	97
C	Primary amide	59	210

(a) Use IUPAC nomenclature to identify compounds A, B and C **3**



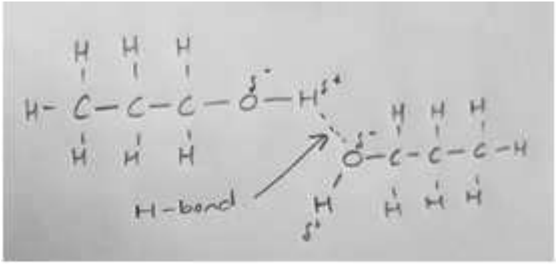
$C_nH_{2n+2} = 58$	$C_nH_{2n+2}O = 60$	
$12n + 2n + 2 = 58$	$12n + 2n + 2 + 16 = 60$	C + O + N =12+ 16 + 14 + 2 = 44
n = 4	n = 3	$59 – 44 = 15 = CH_3$
C_4H_{10}	C_3H_7OH	CH_3CONH_2

A butane B propan-1-ol C ethanamide

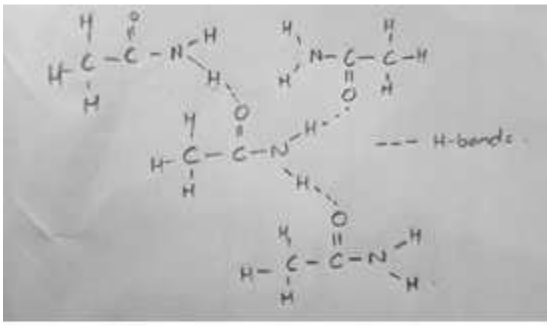
(b) Explain the different boiling points of compounds A, B and C. Use at least ONE labelled diagram to illustrate an explanation. **6**

Butane is non-polar and has the lowest boiling point as there are only weak dispersion forces between the molecules which are easily overcome by small amounts of energy.

Propan-1-ol has both dispersion forces, dipole-dipole interactions and H-bonds between molecules. H-bonds occur between the polar hydroxyl groups on the molecules, so, even though its molar mass is similar to butane, it takes
more energy to overcome the H-bonds and therefore the boiling point is much higher than butane.



Ethanamide has the highest boiling point as it has more extensive hydrogen bonding between the molecules. This is possible because there is both a carbonyl group and an amine group on the short chain. The oxygen in the carbonyl group is slightly negative because of the polar C=O bond and dipole-dipole forces can occur from this group. The hydrogens in the amine are slightly positive and the nitrogen, negative. This allows for more extensive hydrogen bonding between the molecules.
SGS note: Always show lone pair on H-bond acceptors, for example, on the oxygen atom of the C=O group.



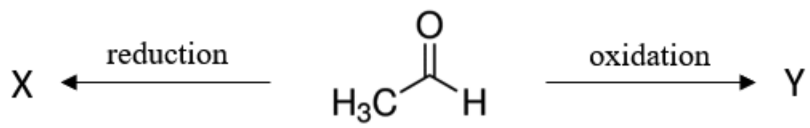
Marking Criteria	*Mark(s)*
• Explains the 3 different boiling points • Uses at least one labelled relevant diagram to illustrate strong intermolecular forces	6
• Explains the 3 different boiling points • Shows a diagram with small errors or insufficient labelling OR • Explains 2 and outlines one boiling point • Uses at least one labelled relevant diagram to illustrate strong intermolecular forces	5
• Explains the different boiling points for two compounds OR • Outlines 3 boiling points AND • Shows a diagram with small errors or insufficient labelling	4
• Explains the differences in the boiling points for two of the compounds OR • Outlines 3 boiling points	3
• Outlines the boiling points for two compounds OR • Outlines some intermolecular forces or functional groups	2
• Gives some relevant information	1

Question 32 (7 marks)

In organic chemistry, oxidation and reduction reactions occur as opposing reactions shown.

$$A \underset{\text{reduction}}{\overset{\text{oxidation}}{\rightleftharpoons}} B$$

The following reaction scheme can be used to synthesise two organic compounds from ethanal.



Identify the products X and Y and outline how the results of chemical tests and instrumental techniques (infrared and carbon NMR spectroscopy) could be used to confirm the identity of these compounds. **7**

Sample answer:

The product X is ethanol and Y is ethanoic acid. The production of ethanoic acid from ethanal could be confirmed using chemical tests such as using blue litmus paper which would turn red *due to the presence of a carboxylic acid group or treatment with a carbonate salt like sodium carbonate that would react with the acid to give off carbon dioxide gas. Chemical tests that could be used to confirm that ethanol has been produced from ethanal include placing a small piece of sodium metal in the resultant solution that would react vigorously to produce hydrogen gas.*

These formation of these products from ethanal can also be confirmed using instrumental techniques. For instance, we can confirm that X is ethanol using infrared spectroscopy where the C=O stretch at 1680 – 1750 cm^{-1} in ethanal would be replaced with the broad O-H stretch at 3230 – 3550 cm^{-1} and C–O stretch at 1000 – 1300 cm^{-1} which are features of the alcohol functional group present in ethanol. Similarly for the carbon NMR the C=O aldehyde signal at 190 – 220 ppm in ethanal would be replaced with an C–O alcohol signal at 50 – 90 ppm. The carbon NMR spectra for both compounds would also contain a C–C signal for the carbon chain at 5 – 40 ppm. This manner differs in how we confirm that Y is ethanoic acid, where rather than replacing peak signals we add to or move them instead. Using infrared spectroscopy we should see that the C=O stretch at 1680 – 1750 cm^{-1} in ethanal is still present, but accompanied by a broad O-H stretch at 3230 – 3550 cm^{-1} and C–O stretch at 1000 – 1300 cm^{-1} in ethanoic acid. Similarly for the carbon NMR the C=O aldehyde signal at 190 – 220 ppm in ethanal would shift upfield to 160 – 185 ppm in accordance with the standard range for C=O carboxylic acid signals.

Marking Criteria	*Mark(s)*
• Correctly identifies both products. • Outlines a chemical test and the relevant observation to identify each product. • Outlines relevant features from infrared and carbon NMR data for each and explains how the identity is confirmed.	6 – 7
• Correctly identifies at least one product or the functional groups present in both products. • Outlines a chemical test and relevant observations for one or both products. • Outlines relevant features from infrared and carbon NMR data for one or both products. **OR** • Outlines relevant features from infrared and carbon NMR data for each and explains how the identity is confirmed.	4 – 5
• Identifies at least one product or the functional group present in one product. • Outlines a chemical test and relevant observation for one product • Outlines relevant features from infrared and / or carbon NMR data for one product.	2 – 3
• Provides some relevant information	1

Question 33 (7 marks)

A manufacturer of a commercial brand of antacid claimed that each tablet had 99.9% magnesium carbonate. An analytical chemist followed the procedure described below to verify the manufacturer's claim.

1. A tablet was weighed then placed in a conical flask. The mass of the tablet was 0.747 g.

2. A bulb pipette was used to add 20.0 mL 0f 0.996 mol L^{-1} hydrochloric acid to the tablet in the conical flask.

3. After the reaction between the tablet and the hydrochloric acid had stopped, the mixture was gently boiled for 10 minutes. Then, 10.0 mL of demineralised water was added to the mixture in the conical flask.

4. Two drops of phenolphthalein indicator were added to the conical flask. This mixture was titrated with 0.110 mol L^{-1} of sodium hydroxide solution to neutralise the excess hydrochloric acid.

5. The average volume of sodium hydroxide solution required to change the colour of the indicator was 22.39 mL.

(a) Calculate the moles of acid in excess after the first reaction. **2**

$$HCl + NaOH \rightarrow NaCl + H_2O$$

n(NaOH) required to react with excess HCl = c x V = 0.2239 x 0.11 = 0.002463 mol

n(HCl) in excess = n(NaOH) = 0.002463 mol

Marking Criteria	*Mark(s)*
• Correctly calculates the moles in excess	2
• Shows some working	1

(b) Determine the percentage of magnesium carbonate in the antacid tablet and assess the accuracy of the manufacturer's claims. **5**

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$$

n(HCl) initially added = c x V = 0.0200 x 0.996 = 0.01992 mol

n(HCl) reacted with tablet = 0.01992 – 0.002463 = 0.01746 mol

$n(MgCO_3)$ in tablet = half the moles of HCl = 0.01746 / 2 = 0.008729 mol

mass $MgCO_3$ = mol x MM = 0.008729 x (24.3 + 12.01 + 3(16)) = 0.7358 g

% $MgCO_3$ in tablet = (0.736/0.747) x 100 = 98.5 %

The manufacturer's claim is inaccurate (not accurate).

Marking Criteria	*Mark(s)*
• Correctly calculates the % showing all relevant working and assesses the manufacturer's claim as inaccurate	5
• Correctly calculates the % showing all relevant working OR • Correctly calculates the % showing most relevant working AND assesses the manufacturer's claim as inaccurate	4
• Correctly calculates the % showing most relevant working	3
• Shows some calculations	2
• Gives some relevant information	1

Question 34 (4 marks)

A student prepares a solution consisting of 6.0 mol L^{-1} ammonium chloride and 0.40 mol L^{-1} of ammonia.

(Assume complete dissociation of ammonium chloride in the solution)

At 25°C : $Ka(NH_4^+) = 6.3 \times 10^{-10}$

(a) Write a net ionic equation for the reaction of ammonium chloride with water. **1**

$$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$$

Marking Criteria	*Mark(s)*
• Correct ionic equation	1

(b) Write the Ka expression for the reaction in (a). **1**

$$Ka = [NH_3]\,[H_3O^+] \;/\; [NH_4^+]$$

Marking Criteria	*Mark(s)*
• Correct Ka expression for ammonium chloride	1

(c) Calculate the pH of the prepared solution. **2**

Let $[H_3O^+] = [H^+] = x$, and assume $[NH_4^+] = 6.00$ and $[NH_3] = 0.400$

Therefore $6.3 \times 10^{-10} = [H^+] \times 0.400 / 6.00$

$[H^+] = 9.45 \times 10^{-9}$

$pH = -\log_{10}[H^+] = 8.02$