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CHEMISTRY MOCK EXAM

NESA Number

2020 HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- Write your NESA number where required

Total marks: 100

Section I – 20 marks (pages 2-9)

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

Section II – 80 marks (pages 10-27)

- Attempt Questions 21-37
- Allow about 2 hours and 25 minutes for this section

Section I: Multiple Choice Questions (20 marks)
Attempt Questions 1 – 20
Allow about 35 minutes for this section

Use the multiple choice answer sheet for Questions 1 – 20.

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. Phosgene ($COCl_2$) can be prepared from a reaction between carbon monoxide and chlorine:

$$CO_{(g)} + Cl_{2(g)} \rightleftharpoons COCl_{2(g)} \qquad \Delta H < 0$$

Which of the following will increase the yield of phosgene at equilibrium?

(A) Increasing the temperature of the system

(B) Removing carbon monoxide from the system

(C) Decreasing the volume of the system

(D) Adding argon gas into the system to increase the pressure

2. Which of the following is a conjugate acid/base pair that can act as a buffer?

(A) HNO_3/NO_3^-

(B) H_3PO_4/PO_4^{3-}

(C) NH_4^+/NH_3

(D) SO_4^{2-}/SO_3^{2-}

3. Consider the following organic compound where two of the carbon atoms have been labelled as C^a and C^b:

$$CH_3 — C^aH_2 — CH_2 — C^b \equiv N$$

Which row of the following table correctly shows the type of shape formed by the bonds around the C^a and C^b atoms?

	$\mathbf{C^a}$	$\mathbf{C^b}$
(A)	Tetrahedral	Linear
(B)	Trigonal planar	Linear
(C)	Tetrahedral	Tetrahedral
(D)	Linear	Trigonal planar

4. Which of the following species is NOT amphiprotic?

(A) H_2O

(B) CH_3COO^-

(C) HPO_4^{2-}

(D) HCO_3^-

5. Which of the following options contains a pair of structural isomers where the boiling point of the first compound is lower than that of the second compound?

(A) Pentanoic acid and hexanoic acid

(B) Butanoic acid and ethyl ethanoate

(C) Propan-1-ol and propan-2-ol

(D) 2-methylpropane and butane

6. Consider the following reaction:

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

In an experiment, 6.0 moles of N_2O_4 and 1.0 mole of NO_2 was injected into a 0.50 L container at 100°C and allowed to react until equilibrium was attained. The equilibrium constant for this reaction is 0.212 at 100°C.

Which row of the following table correctly identifies the direction in which the reaction will proceed to reach equilibrium and the reason for this shift?

	Direction favoured	**Reason**
(A)	Left	$Q > K$
(B)	Left	$Q < K$
(C)	Right	$Q > K$
(D)	Right	$Q < K$

7. A laboratory contains solutions of a weak monoprotic acid (HA) and a strong monoprotic acid (HB), both at the same volume and concentration.

Which of the following statements regarding these two solutions is correct?

(A) HA has a lower pH than HB

(B) HA has a higher hydronium ion concentration than HB

(C) The concentration of A^- in HA is higher than the concentration of B^- in HB

(D) Both solutions would be neutralised by the same volume of 0.10 mol L^{-1} NaOH

8. Benzoic acid (C_6H_5COOH) is a weak monoprotic acid that can be used as a primary standard for titrations. A 0.15 mol L^{-1} solution of benzoic acid has a pH of 2.51.

What is the pK_b of the benzoate ($C_6H_5COO^-$) ion?

(A) 3.60

(B) 4.19

(C) 9.81

(D) 10.40

9. A sample of magnesium hydroxide was added to 0.0500 mol L^{-1} sodium hydroxide solution and only some of the magnesium hydroxide dissolved.

What is the solubility of magnesium hydroxide in this solution?

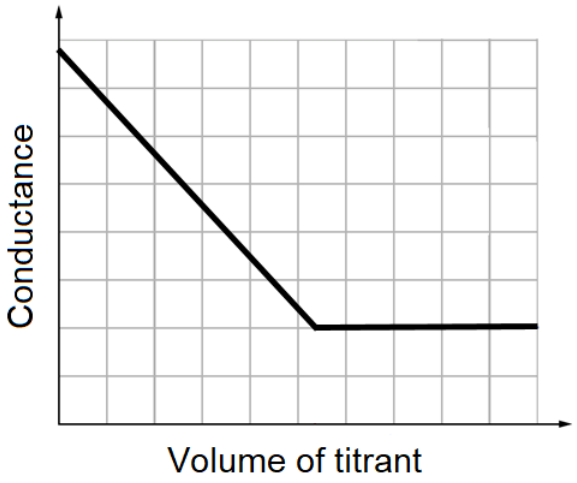
(A) 2.24×10^{-9} mol L^{-1}

(B) 3.38×10^{-9} mol L^{-1}

(C) 4.52×10^{-9} mol L^{-1}

(D) 5.26×10^{-9} mol L^{-1}

10. In a particular titration, a base from a burette was delivered into a conical flask containing an acid. The conductivity curve below was produced from monitoring the conductivity of the conical flask solution during the titration.



Which of the following titrations would produce the conductivity curve above?

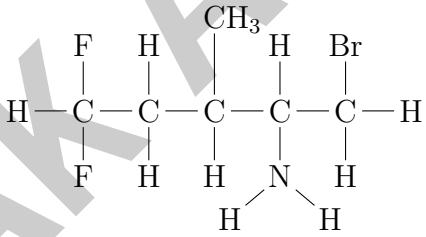
(A) $HCl + KOH$

(B) $HCl + NH_3$

(C) $CH_3COOH + KOH$

(D) $CH_3COOH + NH_3$

11. Consider the following organic compound:



What is the systematic name of this compound?

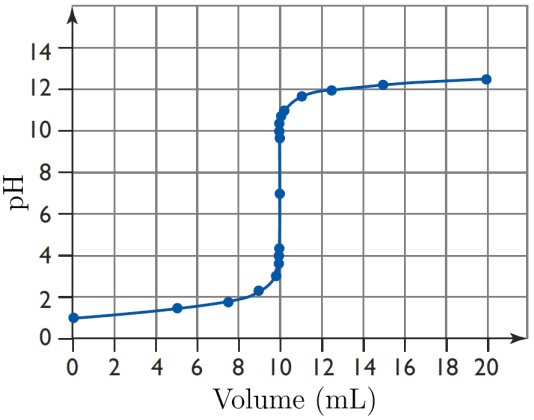
(A) 1-bromo-5,5-difluoro-3-methylpentan-2-amine

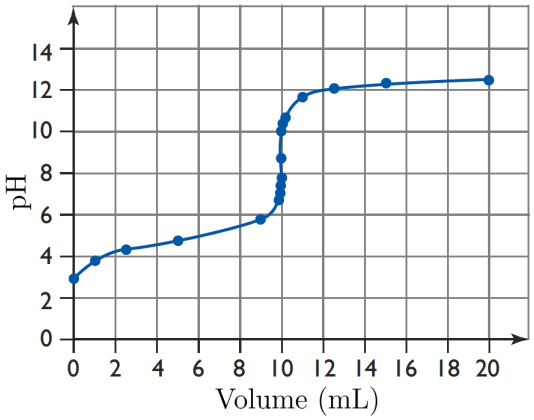
(B) 1-bromo-5,5-difluoro-3-methylpentan-2-amide

(C) 5-bromo-1,1-difluoro-3-methylpentan-4-amine

(D) 5-bromo-1,1-difluoro-3-methylpentan-4-amide

12. Consider the following titration curves that are produced from two different titrations:





Which row of the following table contains an indicator that would be suitable for BOTH titrations?

	Indicator	pH range	Colour (Low pH)	Colour (High pH)
(A)	Congo red	3.0 – 5.0	Blue	Red
(B)	Methyl red	4.4 – 6.2	Red	Yellow
(C)	Thymol blue	8.0 – 9.6	Yellow	Blue
(D)	Indigo carmine	11.4 – 13.0	Yellow	Blue

13. In a calorimetry experiment, butan-1-ol was completely combusted to heat 150.0 mL of water from 20.0°C to 70.0°C. The molar heat of combustion of butan-1-ol is 2670 kJ mol^{-1}.

If only 65.0% of the heat released by the combustion was absorbed by the water, what volume of carbon dioxide gas was produced at 25°C and 100 kPa?

(A) 1.06 L

(B) 1.16 L

(C) 1.64 L

(D) 1.79 L

14. A 25.0 mL solution of 0.15 mol L^{-1} hydrochloric acid was mixed with a 20.0 mL solution of 0.20 mol L^{-1} potassium hydroxide.

What is the pH of the resultant solution?

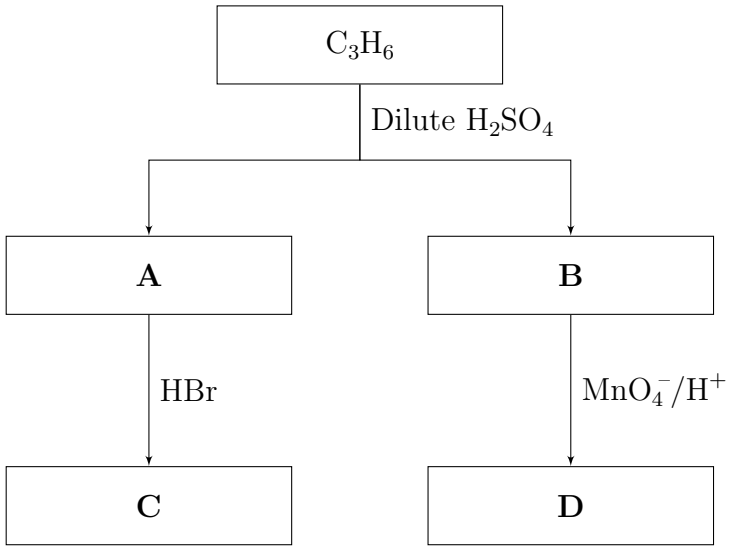
(A) 2.26

(B) 3.60

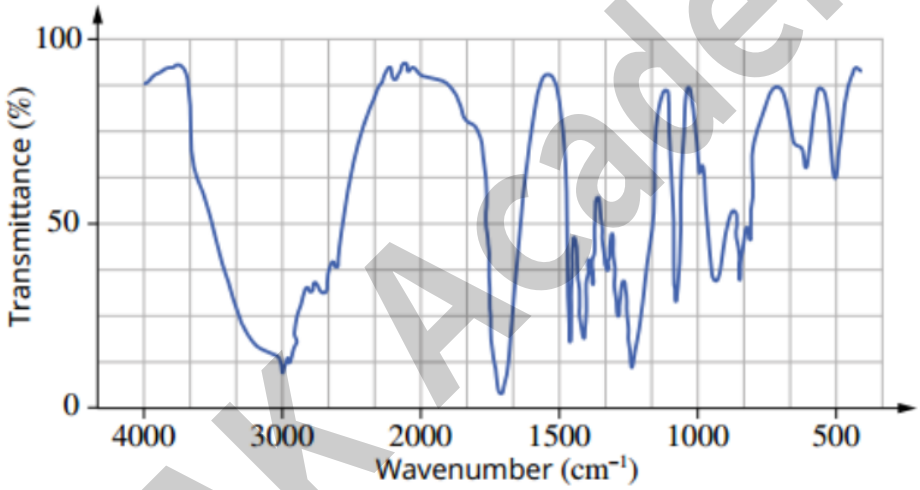
(C) 10.40

(D) 11.74

15. Consider the following series of reactions where **A** to **D** are different organic compounds.



The infrared (IR) spectrum of compound **D** is given below.



Based on the above information, the identity of compound **C** is:

(A) 1-bromopropane

(B) 2-bromopropane

(C) 1-bromopropan-1-ol

(D) 2-bromopropan-2-ol

16. A white solid was added to nitric acid and bubbling was observed. When the resultant mixture was tested with a flame test, a brick red flame colour was observed.

What is the most likely identity of the white solid?

(A) Barium sulfate

(B) Barium carbonate

(C) Calcium carbonate

(D) Calcium sulfate

17. In an experiment, 0.570 g of an unknown sample was analysed for its phosphate content. Excess calcium nitrate was added to an aqueous solution of the unknown sample to precipitate out the phosphate ions. The precipitate that formed had a mass of 0.125 g.

What is the theoretical percentage by mass of phosphate in the unknown sample?

(A) 6.75%

(B) 13.4%

(C) 15.4%

(D) 30.8%

18. Which of the following substances is a liquid that readily decolourises bromine water under standard conditions?

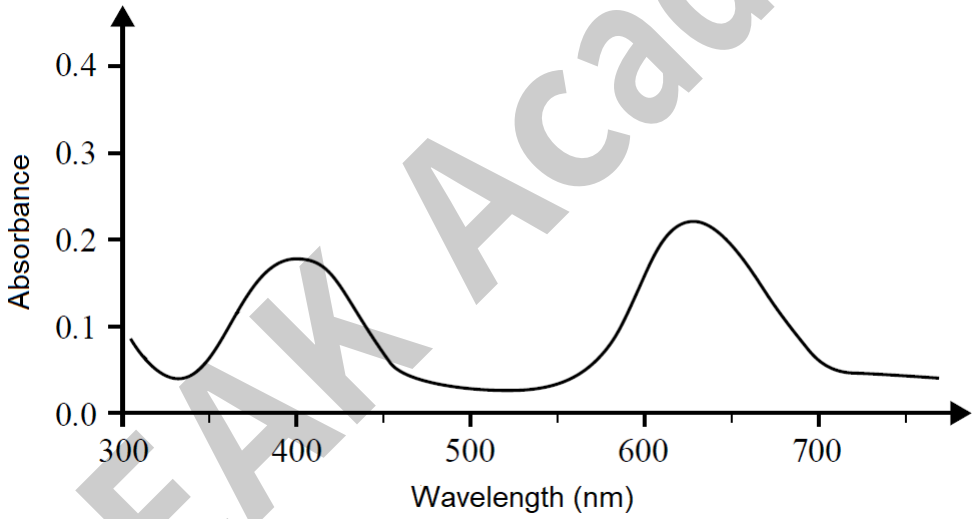
(A) Ethene

(B) Cyclohexane

(C) Benzene

(D) Hex-2-ene

19. The ultraviolet-visible (UV-vis) spectrum below shows how the absorbance varies over a range of wavelengths for a solution containing a particular inorganic compound.



In an experiment to determine the concentration of the inorganic compound in this solution, light from a lamp was passed through the solution to a detector and the following intensities of light were then measured:

- $I(x \text{ nm})$ = Intensity of light at a wavelength of x nm from the lamp
- $I_{\text{d}}(x \text{ nm})$ = Intensity of light at a wavelength of x nm at the detector

Which of the following pairs of intensities should be used to determine the concentration of the inorganic compound in this solution using UV-vis spectroscopy?

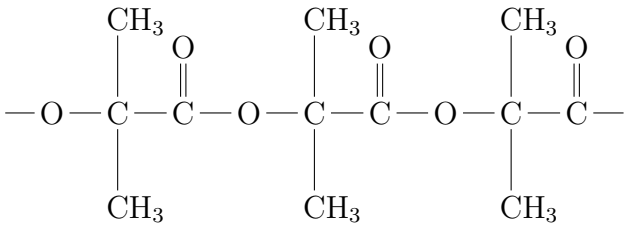
(A) $I(510 \text{ nm})$ and $I_{\text{d}}(510 \text{ nm})$

(B) $I(625 \text{ nm})$ and $I_{\text{d}}(625 \text{ nm})$

(C) $I(510 \text{ nm})$ and $I_{\text{d}}(625 \text{ nm})$

(D) $I_{\text{d}}(510 \text{ nm})$ and $I_{\text{d}}(625 \text{ nm})$

20. A section of a polymer containing three monomer units is shown below.



When this polymer is formed from its monomer, water is produced as a by-product.

The monomer used to directly produce the polymer above was analysed with nuclear magnetic resonance (NMR) spectroscopy.

Excluding the signal given by the tetramethylsilane (TMS) reference, the monomer would give:

(A) 1 signal on a ^{1}H NMR spectrum and 3 signals on a ^{13}C NMR spectrum

(B) 3 signals on a ^{1}H NMR spectrum and 3 signals on a ^{13}C NMR spectrum

(C) 3 signals on a ^{1}H NMR spectrum and 4 signals on a ^{13}C NMR spectrum

(D) 4 signals on a ^{1}H NMR spectrum and 4 signals on a ^{13}C NMR spectrum

Section II: Short Answer Questions (80 marks)
Attempt Questions 21 – 37
Allow about 2 hours and 25 minutes for this part

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.

Question 21 (4 marks)
Hydrochloric acid and acetic acid are both common acids with very different properties.

(a) Calculate the pH of a 0.10 mol L^{-1} acetic acid solution given that the pK_a of acetic acid is 4.76. **3**

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(b) Account for the differences in pH between an acetic acid solution and a hydrochloric acid solution of the same concentration. **1**

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Question 22 (3 marks)

Addition polymers such as polyethylene are versatile materials that are used for many household applications. Two such uses of polyethylene are shown in the photos below. **3**

Glad wrap

Bucket

Explain, in terms of its structure and properties, why polyethylene can be used for the two applications shown above.

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Question 23 (3 marks)

When sodium acetate is dissolved in water, the resultant solution has a pH greater than 7. **3**

Explain why the Brönsted-Lowry theory can account for this result whereas the Arrhenius theory cannot. Include a relevant chemical equation in your answer.

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Question 24 (7 marks)

2.69 moles of hydrogen sulfide gas was mixed with 0.300 moles of sulfur dioxide gas in a 3.50 L container and allowed to react at 100°C according to the following equation:

$$2\,H_2S_{(g)} + SO_{2(g)} \rightleftharpoons 3\,S_{(s)} + 2\,H_2O_{(g)}$$

At equilibrium, the concentration of water vapour was found to be 0.120 $mol\,L^{-1}$.

(a) Using the information above, calculate the equilibrium constant for this reaction at 100°C. **3**

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(b) Outline how the equilibrium system and the equilibrium constant will be affected if the volume of the container is increased. **2**

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(c) The equilibrium constant for this reaction decreases when the system is heated. **2**

Predict whether the reaction is endothermic or exothermic and justify your answer.

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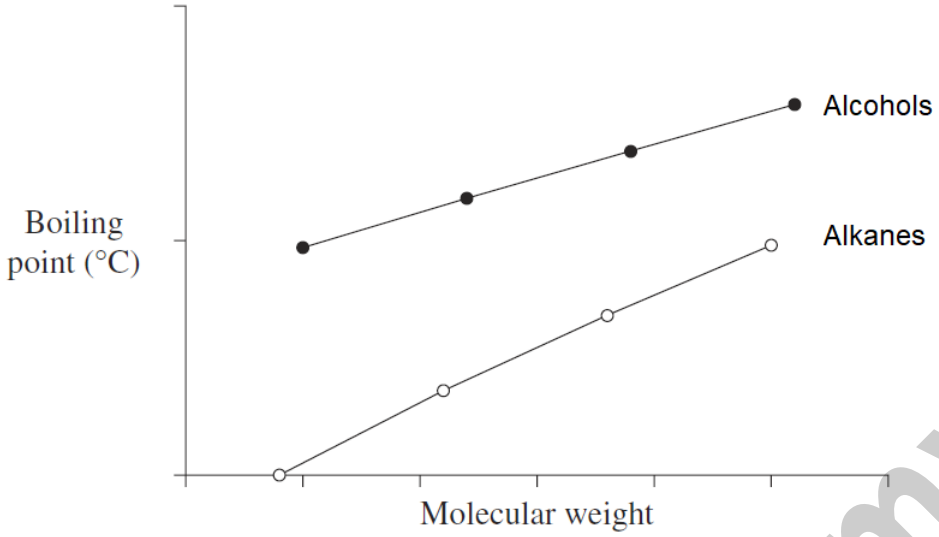
Question 25 (4 marks)

The graph below shows how the boiling points of two different homologous series varies with molecular mass.



(a) Explain the trends shown in the graph above. **3**

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(b) On the graph above, draw a line to roughly show how the boiling points of carboxylic acids will compare with the alcohols and justify your answer. **1**

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Question 26 (4 marks)

An aqueous solution is known to contain a red molecule (HInd) and a blue anion (Ind^-).

(a) Explain, in terms of Le Chatelier's principle, why this solution can be used as an acid-base indicator. Include a relevant chemical equation in your answer. **3**

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(b) A dilute aqueous solution of acetic acid causes dry, blue litmus paper to turn red. However, when glacial (pure) acetic acid is added to dry, blue litmus paper, no colour change is observed. **1**

Propose a reason for this observation.

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Question 27 (8 marks)
In an organic chemistry laboratory, a student was asked to synthesise ethyl propanoate.

(a) Describe a reaction pathway that can be used to theoretically synthesise ethyl propanoate using ethene and 1-chloropropane as the ONLY starting organic reagents. Include relevant chemical equations using structural formulae in your answer. **4**

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(b) Explain why refluxing is used to produce esters. Include a relevant diagram in your answer. **4**

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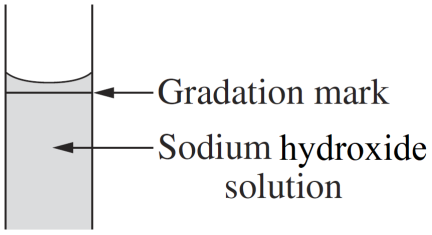
Question 28 (3 marks)

A student was asked to standardise a solution of sodium hydroxide by titrating it against a benzoic acid primary standard solution. The procedure used by the student is outlined below. **3**

1. A conical flask was rinsed with distilled water only.
2. A 25.0 mL pipette was rinsed with distilled water and then with the sodium hydroxide solution.
3. A pipette filler was used to fill the pipette with the sodium hydroxide solution to the level shown in the diagram below.



4. The sodium hydroxide solution in the pipette was transferred to the conical flask. Three drops of an appropriate indicator was added to the conical flask.
5. A burette was rinsed with distilled water only and then filled with the benzoic acid solution. The student then carried out the remainder of the titration appropriately.

The student did not follow acceptable procedures for this titration.

Explain the effect of the mistakes made by the student on the calculation of the concentration of the sodium hydroxide solution.

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Question 29 (7 marks)

The production of new materials is driven by the recognition that traditional products may no longer be satisfactory in some aspect of their use or supply. **7**

Evaluate the potential of ethanol as an alternative fuel to petrol (octane) with reference to the current progress that has been made. Include relevant chemical equations in your answer.

Question 30 (4 marks)
A 25.0 mL solution of 0.0100 mol L^{-1} silver nitrate is mixed with 25.0 mL of 0.0150 mol L^{-1} potassium sulfate solution at 25°C.

(a) Using relevant calculations, predict if silver sulfate will form as a precipitate under these conditions. **3**

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(b) Draw a diagram to show the interactions between water molecules and the ions present in a potassium sulfate solution. **1**

Question 31 (5 marks)

Aspirin tablets are often used for pain relief. A chemist performed an investigation on a tablet to determine the proportion of aspirin ($C_9H_8O_4$) in it.

The chemist crushed up a 1.95 g tablet and dissolved it in 250.0 mL of 0.175 mol L^{-1} sodium hydroxide solution. All of the aspirin in the tablet was neutralised according to the following equation:

$$C_9H_8O_{4(s)} + NaOH_{(aq)} \rightarrow NaC_9H_7O_{4(aq)} + H_2O_{(l)}$$

Four 25.0 mL aliquots of the resultant solution were then transferred to separate conical flasks and, in each case, the excess sodium hydroxide was titrated against a 0.100 mol L^{-1} oxalic acid dihydrate primary standard solution. The results are given in the table below.

Titration	**Titre volume (mL)**
1	17.20
2	16.80
3	16.75
4	16.85

(a) Given that oxalic acid dihydrate is a diprotic acid, calculate the moles of leftover sodium hydroxide after the reaction with the tablet. **2**

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(b) Calculate the percentage by mass of aspirin in the tablet that was analysed. **3**

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Question 32 (3 marks)

Describe the molecular structure of soap and explain how soap acts as a cleaning agent. **3**

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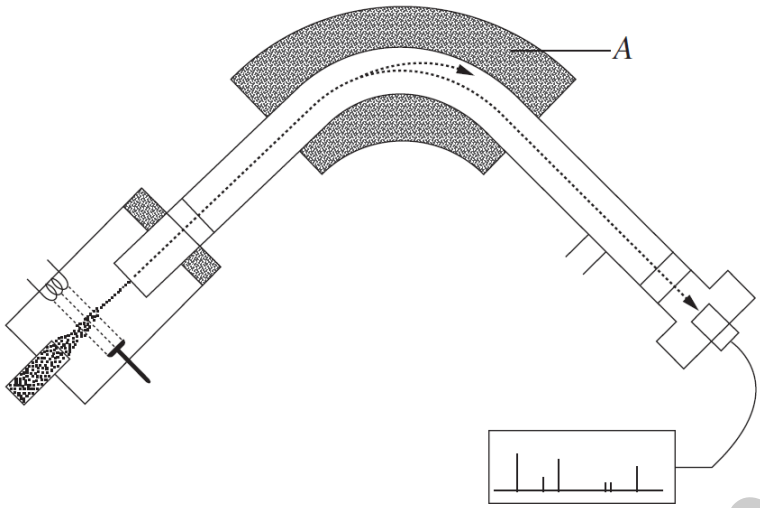
Question 33 (3 marks)
The diagram below shows a schematic diagram of a mass spectrometer.



An analytical chemist analysed a sample of ethanol using mass spectrometry.

(a) Describe how ethanol molecules can be converted into different ions in the ionisation chamber. **2**

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(b) Identify the component of the spectrometer labelled as A on the diagram and outline its role. **1**

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Question 34 (5 marks)
A beaker is known to contain at least one of the following solutions:

- Copper(II) nitrate
- Lead nitrate
- Barium nitrate

(a) Construct a flowchart to demonstrate a series of precipitation tests that could be used to identify the solutions in the beaker. Include any expected observations in your answer. **3**

(b) Write a net ionic equation for the reaction that may occur in the first step of your flowchart in part (a). **1**

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(c) The precipitate that may form in part (b) is commonly mistaken for silver chloride. **1**

Outline an additional test that can be used to distinguish the precipitate in part (b) from silver chloride, along with the expected result.

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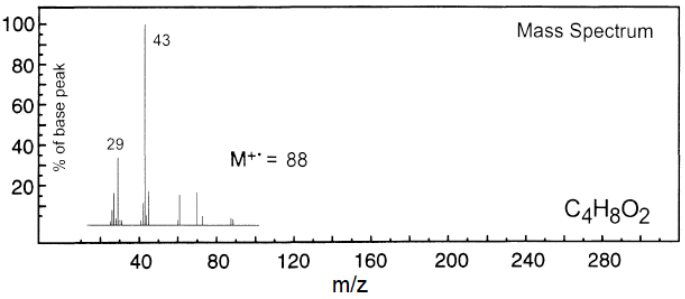
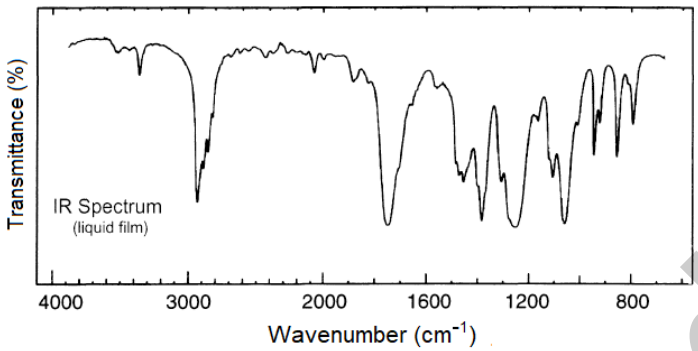
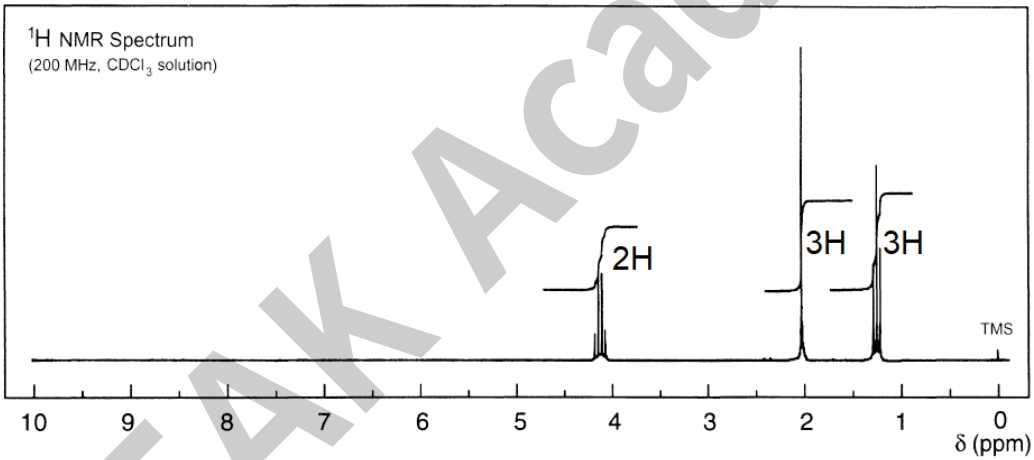
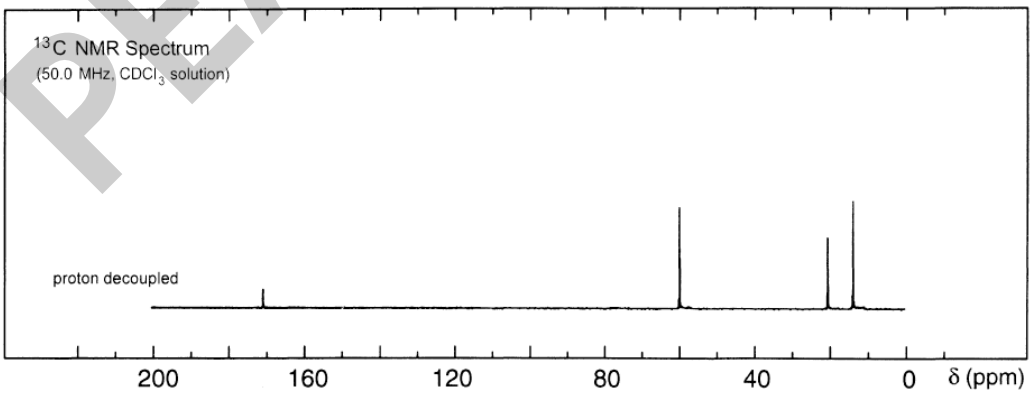
Question 35 (7 marks)

An unknown organic compound with a molecular formula of $C_4H_8O_2$ was analysed with mass spectrometry, infrared (IR) spectroscopy and nuclear magnetic resonance (NMR) spectroscopy. The following spectra were obtained from these techniques. **7**









Describe the information that can be obtained from each of the analytical techniques used, and analyse the spectra above to determine the structural formula of the organic compound.

Note: ^{1}H NMR chemical shift data has been included on your data sheet.

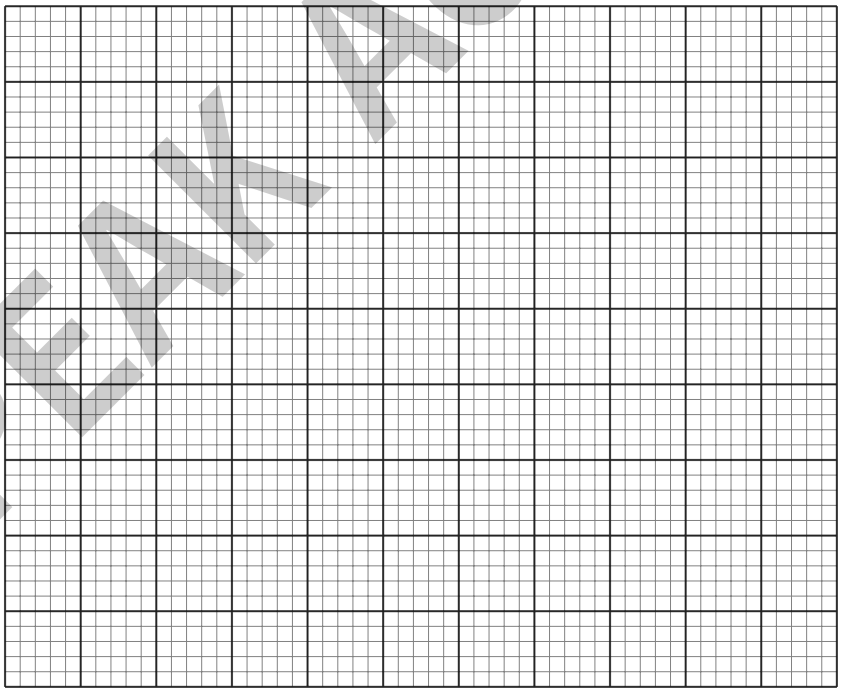
Question 36 (6 marks)

An analytical chemist wanted to analyse a polluted waterway for its mercury content using atomic absorption spectroscopy (AAS). A sample was first prepared for analysis by diluting 10.0 mL of a water sample from the polluted waterway to 100.0 mL in a volumetric flask with distilled water. Three unknown samples were prepared in this way.

Four standard solutions of mercury were then prepared and the absorbances of the standard and unknown solutions were measured relative to a blank. The results are shown in the table below.

Solution	**Mercury concentration (ppm)**	**Absorbance**
Blank	0.00	0.000
Standard A	1.00	0.170
Standard B	2.00	0.330
Standard C	3.00	0.503
Standard D	4.00	0.680
Unknown A	?	0.823
Unknown B	?	0.820
Unknown C	?	0.817

(a) Construct a calibration curve using the information given, and estimate the average concentration of mercury in the polluted waterway. **3**



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(b) Calculate the average mass of mercury in 500.0 mL of water from the polluted waterway in grams. **1**

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(c) Comment on the validity and reliability of the estimate you obtained in part (a). **2**

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Question 37 (4 marks)

In the industrial production of a chemical Z from the reactants X and Y, the equilibrium reaction involved is: **4**

$$X_{(g)} + Y_{(g)} \rightleftharpoons 3\,Z_{(g)} \quad \Delta H > 0$$

Analyse how the temperature and pressure of the reaction vessel could be managed to optimise the industrial production of Z in terms of the yield and reaction rate of the process.

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Section II extra writing space

If you use this space, clearly indicate which question you are answering.