NESA Number: …………………………………

Ascham School

2023 SEMESTER II EXAMINATION

Chemistry

General Instructions	• Reading time – 5 minutes • Working time – 3 hours • Write using black pen • Draw diagrams using pencil • Calculators approved by NESA may be used • A formulae sheet, data sheet and Periodic Table are provided at the back of this paper
Total marks: 100	**Section I – 20 marks** • Attempt Questions 1–20 • Allow about 35 minutes for this part **Section II – 80 marks** • Attempt Questions 21–36 • Allow about 2 hours and 25 minutes for this section

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Section I

20 marks
Attempt Questions 1-20
Allow about 35 minutes for this part

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

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1. What is the measurement taken by an atomic absorption spectrometer?

   A. Absorbance

   B. Volume

   C. Density

   D. Mass

2. Ammonia is produced in the Haber process in the following reaction.

   $N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$

   Magnetite (Fe_2O_3) is a commonly used catalyst for this reaction. In an industrial setting, what will be the effect of magnetite on the equilibrium concentration of hydrogen gas?

   A. A decrease in the rate of reaction

   B. An increase in the rate of reaction

   C. No effect on the concentration of hydrogen gas

   D. A decrease in the concentration of hydrogen gas

3. During crewed space flight, carbon dioxide is removed from the air by "CO_2 scrubbers" containing solid lithium hydroxide. Two relevant equations are:

   $LiOH(s) + H_2O(g) \rightarrow LiOH.H_2O(s)$ $\quad\quad \Delta H = -61.27$ kJ/mol

   $Li_2CO_3(s) + 3H_2O(g) \rightarrow 2LiOH.H_2O(s) + CO_2(g)$ $\quad\quad \Delta H = -28.18$ kJ/mol

   What is the overall ΔH for the scrubbing reaction:

   $2LiOH\,(s) + CO_2\,(g) \rightarrow Li_2CO_3(s) + H_2O(g)$

   A. −33.09 kJ/mol

   B. −84.45 kJ/mol

   C. −94.36 kJ/mol

   D. −178.9 kJ/mol

4. The equilibrium constant for the reaction $Br_2(g) + I_2(g) \rightleftharpoons 2IBr(g)$ is Keq = 1.2×10^2 at 150°C.

   What is Keq for the reaction $4IBr(g) \rightleftharpoons 2Br_2(g) + 2I_2(g)$ at 150°C?

   A. 1.6×10^{-2}

   B. 4.1×10^{-3}

   C. 6.9×10^{-5}

   D. 8.03×10^{-5}

5. The four equations below represent different equilibrium systems.

Equation 1	$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$	$\Delta H = -180$ kJ mol^{-1}
Equation 2	$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$	$\Delta H = -46$ kJ mol^{-1}
Equation 3	$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$	$\Delta H = +93$ kJ mol^{-1}
Equation 4	$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$	$\Delta H = +205$ kJ mol^{-1}

   After equilibrium was established in each system, the temperature was decreased and the pressure was increased.

   In which equilibrium system would both changes result in an increase in yield?

   A. Equation 1

   B. Equation 2

   C. Equation 3

   D. Equation 4

6. Which reagents and conditions are best for converting propan-1-ol into propanoic acid?

   A. Reflux with a metal catalyst

   B. Sunlight with bromine water

   C. Reacting with concentrated sulfuric acid

   D. Heat with acidified potassium dichromate

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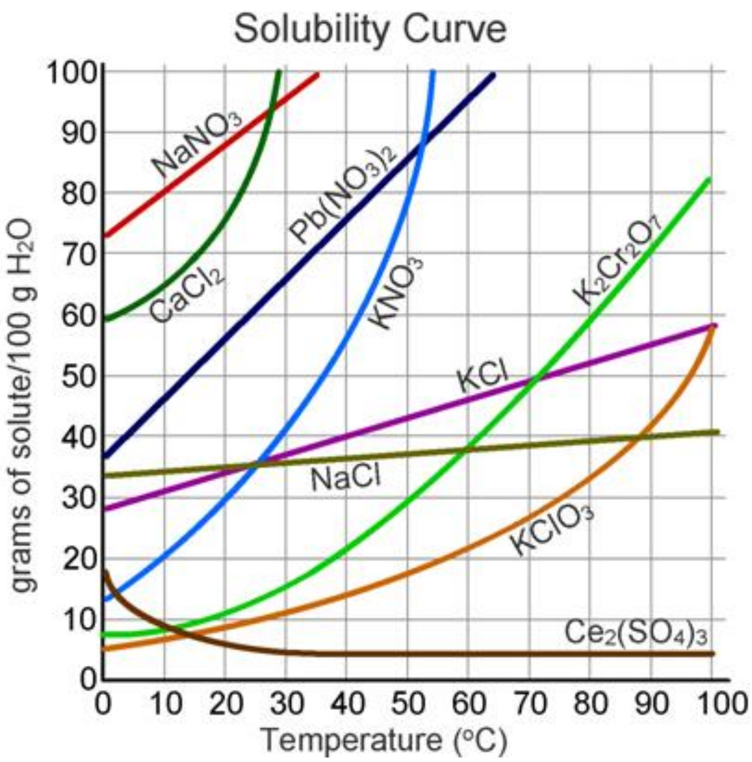
7. A solution was prepared by dissolving 70g of KNO_3 in 200 ml of water at 60°C. The solution was cooled to 10°C. How much KNO_3 will be deposited as a solid?



A. 15g

B. 25g

C. 30g

D. 50g

8. If Solution X has a pH of 3 and Solution Y has a pH of 6, we can conclude that:

A. $[H^+]$ in Solution X is half that of $[H^+]$ in Solution Y

B. $[OH^-]$ in Solution Y is twice that of $[OH^-]$ in Solution X

C. Solution Y must contain a stronger acid than Solution X

D. $[H^+]$ in Solution X is 1000 times that of $[H^+]$ in Solution Y

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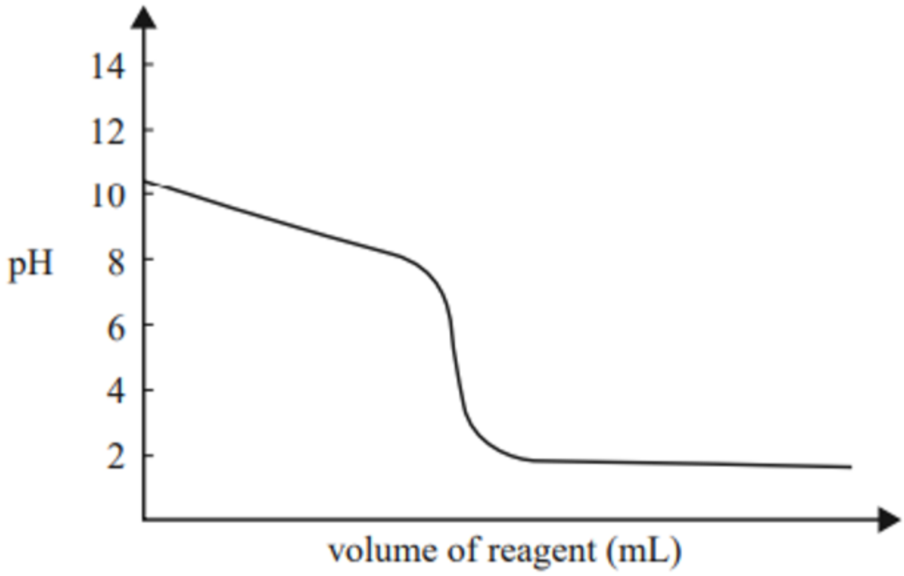
9. The diagram below represents a titration curve for the reaction between a particular acid and a particular base.



Which of these equations best represents the reaction described in the titration curve?

A. HCl *(aq)* + NH_3 *(aq)* → NH_4Cl *(aq)*

B. HCl *(aq)* + $NaOH$ *(aq)* → $NaCl$ *(aq)* + H_2O (l)

C. CH_3COOH *(aq)* + NH_3 *(aq)* → CH_3COONH_4 *(aq)*

D. CH_3COOH *(aq)* + $NaOH$ *(aq)* → CH_3COONa *(aq)* + H_2O (l)

10. What volume of 0.25 mol/L hydrochloric acid is required to react completely with 40 mL of 0.50 mol/L calcium hydroxide?

A. 40 mL

B. 80 mL

C. 120 mL

D. 160 mL

11. Which one of the following represents a conjugate acid-base pair?

A. N^{3-} / CN^{-}

B. NH_3 / NH_2^{-}

C. H_3PO_4 / PO_4^{3-}

D. CH_3CH_2OH / CH_3CHO

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12. Which statement accurately describes the equivalence point in an acid-base titration?

    A. Indicator changes colour

    B. The pH of the solution is 7

    C. The volume of acid equals the volume of base

    D. The mole ratio of acid to base is equal to the stoichiometric ratio

13. One litre of an aqueous solution of potassium hydroxide has a pH of 12.0 at 25°C.
    How many moles of solid potassium hydroxide must be added to raise the pH to 13.0?

    A. 10^{-13}

    B. 10^{-12}

    C. 0.09

    D. 0.10

14. H_2SO_4 and HNO_3 are both strong acids. CH_3COOH is a weak acid. 20.00 mL solutions of 0.10 mol/L concentrations of each of these acids were separately titrated with a 0.10 mol/L solution of NaOH. In order to react completely:

    A. all three acids will require the same amount of NaOH

    B. HNO_3 will require more NaOH than CH_3COOH but less than H_2SO_4

    C. H_2SO_4 and HNO_3 will require the same amount of NaOH but CH_3COOH will require less

    D. CH_3COOH and HNO_3 will require the same amount of NaOH but H_2SO_4 will require more

15. What is produced when 1-chlorobutane is treated with aqueous sodium hydroxide solution?

    A. butane

    B. butanal

    C. butan-1-ol

    D. butanoic acid

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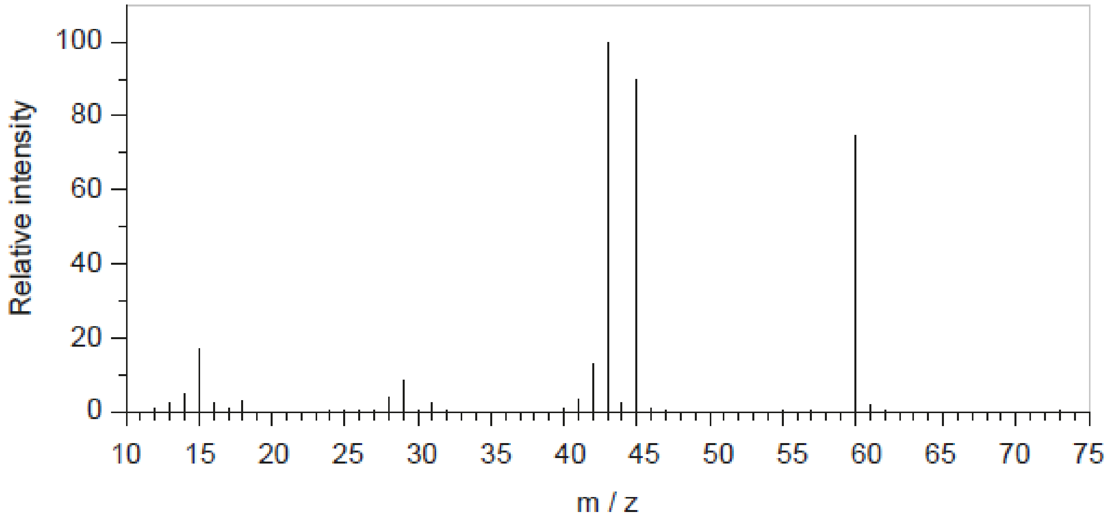
16. Which compound produces this mass spectrum?



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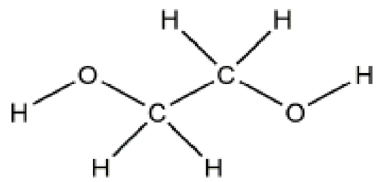

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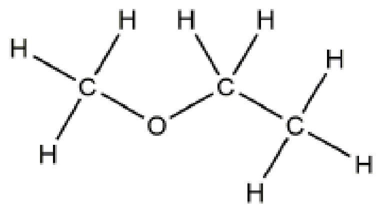

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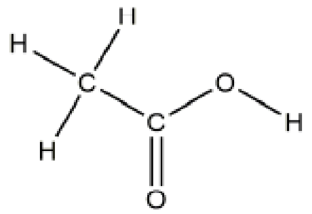

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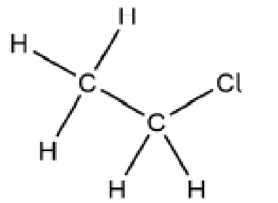
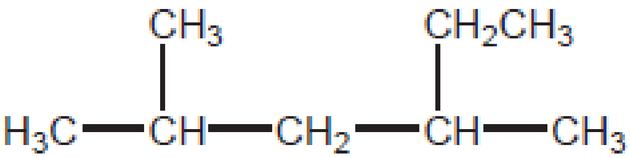


17. What is the IUPAC name of the molecule shown?



A. 2,4-dimethylhexane

B. 3,5-dimethylhexane

C. 2-methyl-4-ethylpentane

D. 2-ethyl-4-methylpentane

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18. What is the ratio of areas under each signal in the ^1H NMR spectrum of 2-methylbutane?

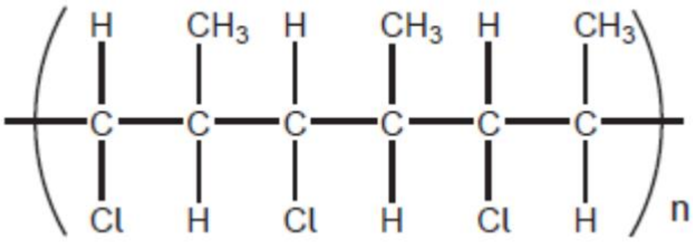
A. 6 : 1 : 5

B. 6 : 1 : 2 : 3

C. 3 : 3 : 1 : 5

D. 3 : 3 : 1 : 2 : 3

19. Which monomer forms the polymer shown?



A. $(CH_3)_2CHCl$

B. $CH(Cl) = CH(CH_3)$

C. $CH_2 = CH(Cl)$

D. $CH_2 = C(Cl)CH_3$

20. Cellulose is a condensation polymer formed from the glucose monomer $C_6H_{12}O_6$.
What would be the molar mass of a cellulose polymer made from 125 monomer units?

A. 20267.5g

B. 20285.5g

C. 22501.5g

D. 22519.5g

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Section II. Answer Booklet

80 marks
Attempt Questions 21 - 36
Allow about 2 hours and 25 minutes for this section

Question 21. (2 marks)

NO_2 reacts to form N_2O_4 as follows:

$$2NO_2\,(g) \rightleftharpoons N_2O_4\,(g) \qquad \Delta H = -57.2 \text{ kJ/mol}$$

Outline what happens to the enthalpy (ΔH) and entropy (ΔS) as this system is cooled.

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Question 22. (3 marks)

Qualitatively compare the solubility of lead (II) chloride in water with its solubility in a solution of sodium chloride. Include an equation in your answer.

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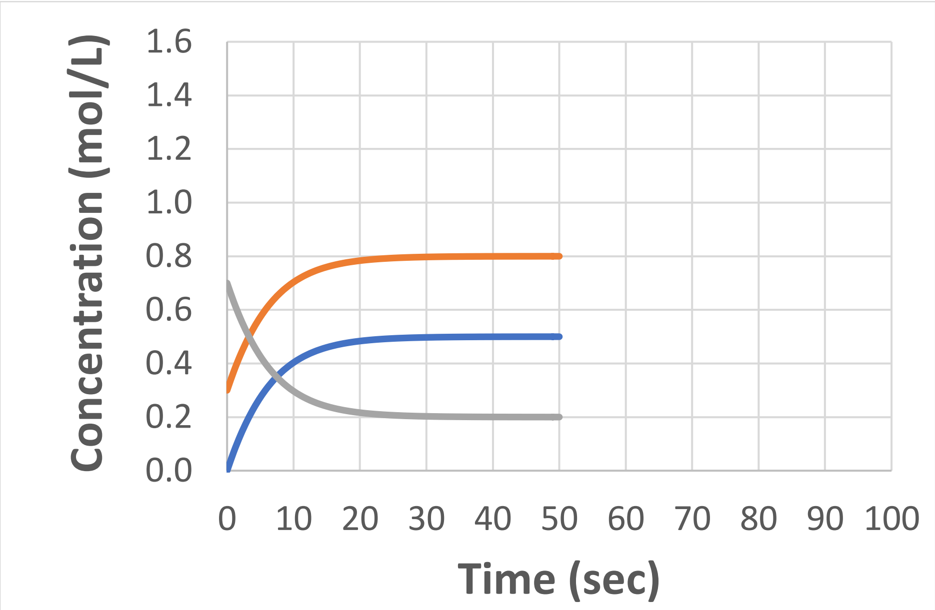
Question 23. (5 marks)

Below is the concentration-time graph for the following reaction system:

$$CO\,(g) + Cl_2\,(g) \rightleftharpoons COCl_2\,(g) \qquad \Delta H = -220 \text{ kJ/mol}$$

At time = 0 seconds, there was no CO gas present in the system.



a) Calculate the equilibrium constant at 40 seconds. **2**

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b) At 50 seconds the volume of the system was halved, keeping the temperature constant. **Continue the graph above** to show how this change would affect the reaction system and how the system would respond to this change until equilibrium is restored. **3**

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Question 24. (4 marks)

Water gas, a mixture of carbon monoxide, hydrogen and oxygen, can react in the following exothermic reaction.

$$H_2\,(g) + CO\,(g) + O_2\,(g) \rightleftharpoons CO_2\,(g) + H_2O\,(g)$$

Use collision theory to explain how the following changes would affect this equilibrium.

a) a decrease in temperature **2**

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b) a decrease in the pressure **2**

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Question 25. (3 marks)

Formic acid (HCO_2H) has a pKa of 3.77. Calculate the pH of a 0.250 mol/L solution of this acid?

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Question 26. (6 marks)

Glycolic acid $CH_2(OH)COOH$, is used in some skincare products.

a) Draw the structural formula of glycolic acid. **1**

b) The equation for the neutralisation of glycolic acid is

$CH_2(OH)COOH\ (aq) + H_2O\ (l) \rightleftharpoons CH_2(OH)COO^-\ (aq) + H_3O^+\ (aq)$ $K_a = 1.48 \times 10^{-4}$

Sodium glycolate, $CH_2(OH)COONa$, is a soluble salt of glycolic acid.

How does the pH of a solution of glycolic acid change when some solid sodium glycolate is dissolved in the solution? Justify your answer. **2**

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100 mL of a 1.00 mol/L solution of glycolic acid is spilt on the floor. This could be neutralized by sodium carbonate. The equation for this reaction is shown below:

$Na_2CO_3\ (s) + 2CH_2(OH)COOH\ (aq) \rightarrow 2CH_2(OH)COONa\ (aq) + H_2O\ (l) + CO_2\ (g)$

c) What is the minimum mass of sodium carbonate that should be used to neutralise the spill?

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Question 27. (5 marks)

a) A buffer of carbonate (CO_3^{2-})/hydrogencarbonate (HCO^-) is present in blood plasma to maintain a pH between 7.35 and 7.45. Write an equation to show the relevant species in this buffer solution. **2**

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b) Explain why 300.0 mL of 1.00 mol/L carbonate/hydrogencarbonate buffer does not change in pH significantly when 3 drops of 1.00 mol/L HCl are added to it, yet when 3 drops of 1.00 mol/L HCl are added to 300.0 mL of distilled water there is a significant change in pH. **3**

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Question 28. (4 marks)

In a beaker 12.00 mL of 0.033 mol/L sulfuric acid solution is added to 32.50 mL of 0.0288 mol/L potassium hydroxide solution. Calculate the pH of the resulting solution. **4**

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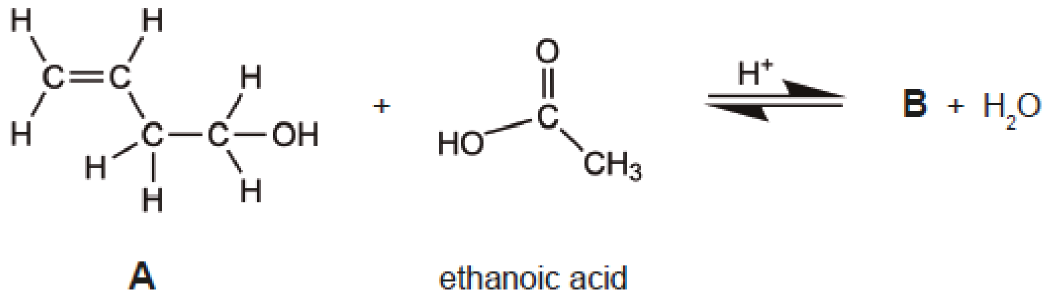
Question 29. (9 marks)

An organic compound, **A**, reacts with ethanoic acid to produce **B** using concentrated sulfuric acid as a catalyst. **3**



a) Draw the structural formula of B. **1**

b) Justify, with reference to Le Châtelier's principle, a method to increase the amount of compound B produced. **2**

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c) Explain, with reference to intermolecular forces, why compound B is more volatile than A. **2**

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Question 29 (continued)

d) Justify safety procedures that are needed in carrying out this reaction in a school Science laboratory. **4**

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Question 30. (4 marks)

Describe two limitations of the Arrhenius theory of acids and bases and how the Bronsted-Lowry model overcomes these limitations.

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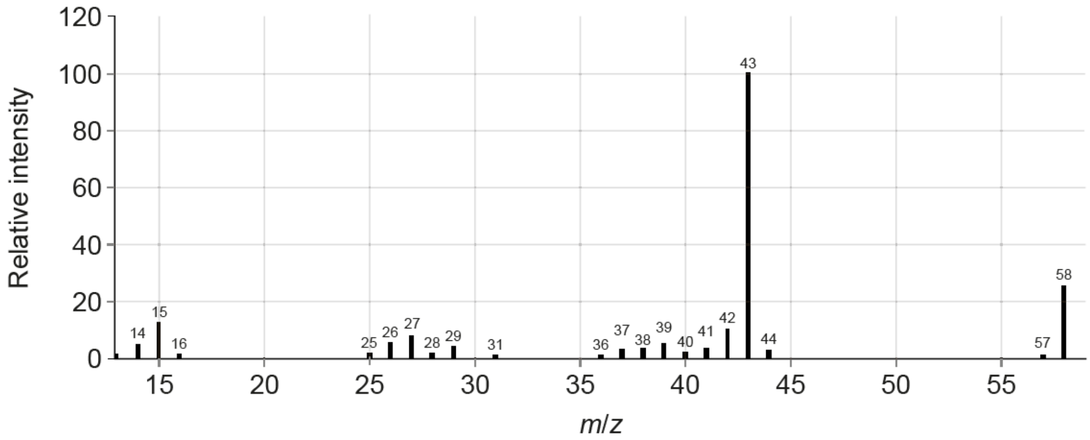
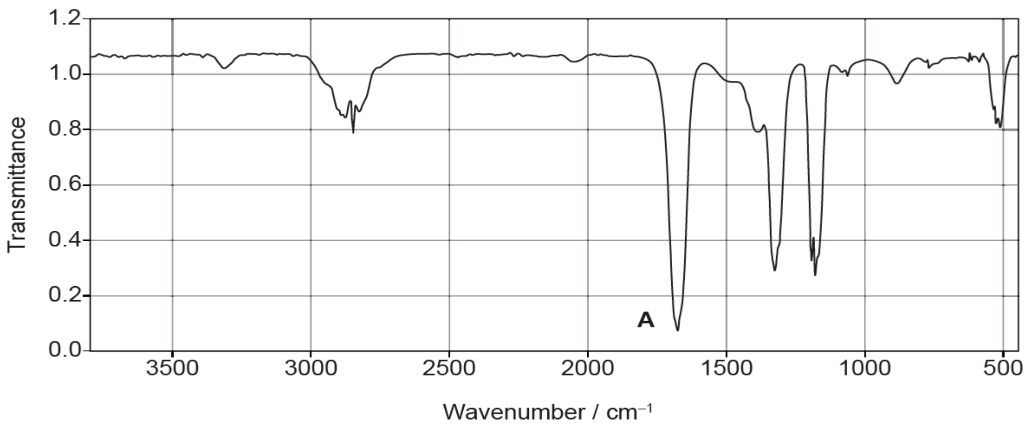
Question 31. (6 marks)

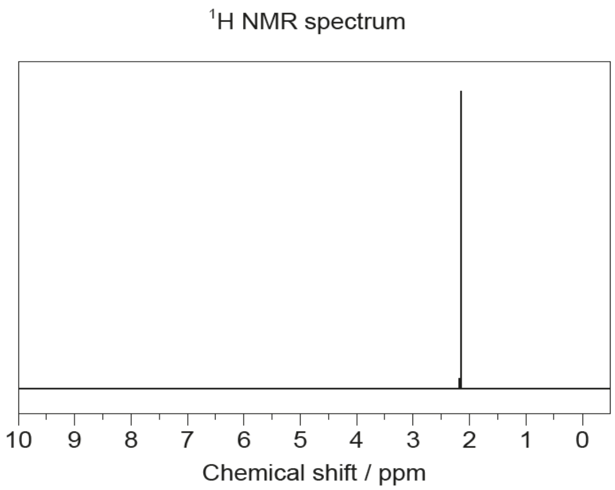
a) Combustion analysis of an unknown organic compound indicated that it contained only carbon, hydrogen and oxygen. Deduce the identity of the unknown compound using all the spectroscopic information shown below. **4**

Mass spectroscopy



Infrared spectrum





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Question 31 (continued)

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b) Draw and name an isomer of the compound identified in part (a). **2**

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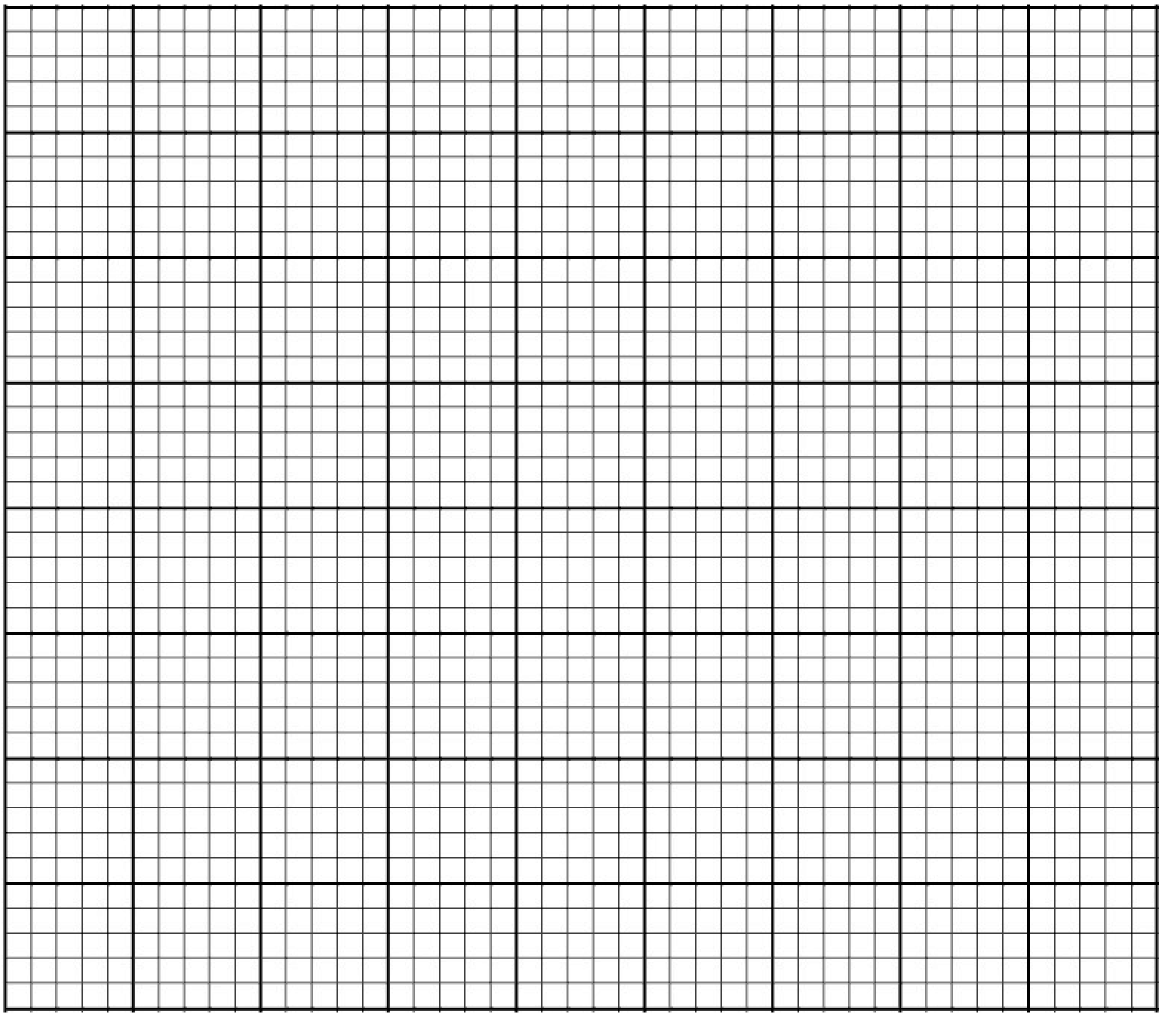
Question 32. (7 marks)

The following data shows the boiling points of primary alcohols and alkanes.

Alkane	Boiling point (°C)	Alcohol	Boiling point (°C)
methane	-164	methanol	65
ethane	-89	ethanol	79
propane	-42	1-propanol	97
butane	-1	1-butanol	117
pentane	36	1-pentanol	138
octane	125	1-octanol	195

Graph the data on the grid below and explain the trends in this data. **7**



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Question 32 (continued)

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Question 33. (4 marks)

Sulfur trioxide, SO_3, is made by the reaction of sulfur dioxide, SO_2, and oxygen, O_2, in the presence of a catalyst, according to the equation below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H < 0$$

In a closed system in the presence of the catalyst, the reaction achieves equilibrium at 1000K.

A mixture of 2.00 mol of $SO_2(g)$ and 2.00 mol of $O_2(g)$ was placed in a 4.00 L evacuated, sealed vessel and kept at 1000 K until equilibrium was reached. At equilibrium, the vessel was found to contain 1.66 mol of $SO_3(g)$.

Calculate the equilibrium constant, Keq, at 1000K.

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Question 34. (5 marks)

A student is given 1 L of a 0.01 mol/L solution of calcium chloride.

a) How many grams of solid KOH will have to be added before a precipitate is formed (assume that the addition of KOH does not change the volume of the solution)? **3**

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b) What will be the pH of the solution immediately before the precipitate starts to form? **2**

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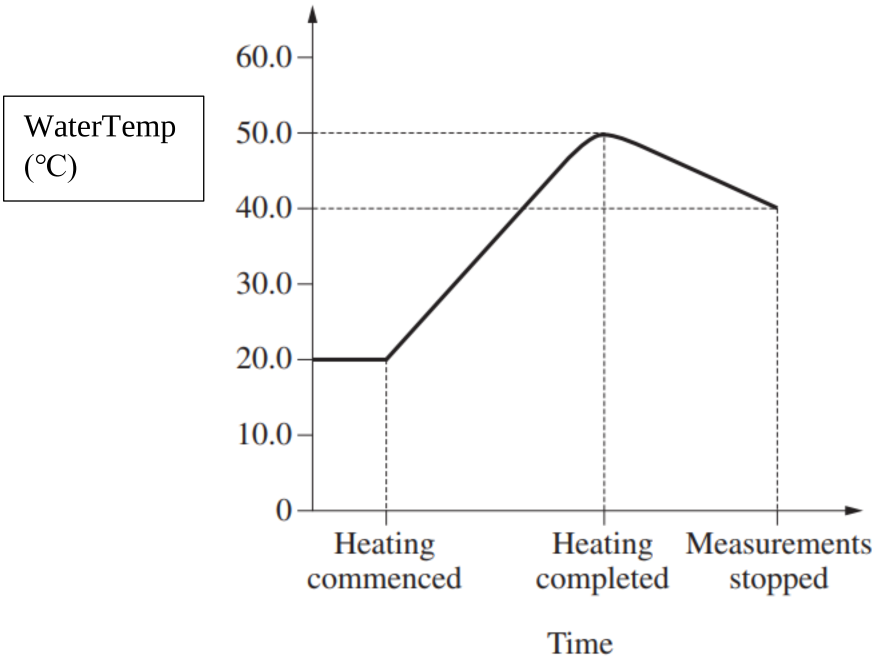
Question 35. (6 marks)

A student wanted to calculate the heat of combustion of butane. They used a spirit burner containing butane to heat up a 120g container of water and the following graph of temperature change was obtained.



At the start of the experiment the weight of the spirit burner was 373.156g and weighed 372.643g at the end of the experiment.

The theoretical molar heat of combustion for butane is $\Delta H_{comb} = -2877$ kJ/mol.

Explain, using quantitative data from your calculations, the reasons for the percentage difference between the experimental and theoretical values and suggest ways that this difference could be minimized.

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Question 36. (7 marks)

Rain with a pH of less than 4.4 is classified as acid rain. Acid rain forms when acidic oxides such as SO_2 dissolve in rainwater to form sulfuric acid.

A 100.0 mL sample of rainwater was collected and diluted to 250 mL with distilled water. 25.0 mL aliquots of diluted rainwater were used in the titration with standardised sodium hydroxide solution.

The sodium hydroxide was standardised against a 3.76×10^{-5} mol/L HCl solution. An average titre of 21.3 mL of this acid was required to neutralise 25.0 mL aliquots of NaOH solution.

When the standardised NaOH solution was titrated with the diluted rainwater the following results were obtained.

Titre volume of NaOH (mL)				Average titre volume (mL
Trial 1	Trial 2	Trial 3	Trial 4	
21.81	19.64	19.67	19.66	

Calculate the pH of the undiluted rainwater sample. Determine if it would be classified as acid rain or not.

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End of paper

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Extra writing pages

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2019 | HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

FORMULAE SHEET

$n = \dfrac{m}{MM}$	$c = \dfrac{n}{V}$	$PV = nRT$
$q = mc\Delta T$	$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$	$\mathrm{pH} = -\log_{10}[\mathrm{H}^+]$
$pK_a = -\log_{10}[K_a]$	$A = \varepsilon lc = \log_{10}\dfrac{I_o}{I}$	

Avogadro constant, N_A ………………………………………… 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and

at 0°C (273.15 K) ………………… 22.71 L

at 25°C (298.15 K) ………………… 24.79 L

Gas constant ………………………………………………… 8.314 J mol^{-1} K^{-1}

Ionisation constant for water at 25°C (298.15 K), K_w ……………… 1.0×10^{-14}

Specific heat capacity of water ………………………………… 4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

Solubility constants at 25°C

Compound	K_{sp}
Barium carbonate	2.58×10^{-9}
Barium hydroxide	2.55×10^{-4}
Barium phosphate	1.3×10^{-29}
Barium sulfate	1.08×10^{-10}
Calcium carbonate	3.36×10^{-9}
Calcium hydroxide	5.02×10^{-6}
Calcium phosphate	2.07×10^{-29}
Calcium sulfate	4.93×10^{-5}
Copper(II) carbonate	1.4×10^{-10}
Copper(II) hydroxide	2.2×10^{-20}
Copper(II) phosphate	1.40×10^{-37}
Iron(II) carbonate	3.13×10^{-11}
Iron(II) hydroxide	4.87×10^{-17}
Iron(III) hydroxide	2.79×10^{-39}
Iron(III) phosphate	9.91×10^{-16}

Compound	K_{sp}
Lead(II) bromide	6.60×10^{-6}
Lead(II) chloride	1.70×10^{-5}
Lead(II) iodide	9.8×10^{-9}
Lead(II) carbonate	7.40×10^{-14}
Lead(II) hydroxide	1.43×10^{-15}
Lead(II) phosphate	8.0×10^{-43}
Lead(II) sulfate	2.53×10^{-8}
Magnesium carbonate	6.82×10^{-6}
Magnesium hydroxide	5.61×10^{-12}
Magnesium phosphate	1.04×10^{-24}
Silver bromide	5.35×10^{-13}
Silver chloride	1.77×10^{-10}
Silver carbonate	8.46×10^{-12}
Silver hydroxide	2.0×10^{-8}
Silver iodide	8.52×10^{-17}
Silver phosphate	8.89×10^{-17}
Silver sulfate	1.20×10^{-5}

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for this examination paper. Some data may have been modified for examination purposes.

NESA Number: ………………………………….

Infrared absorption data

Bond	Wavenumber/cm^{-1}
N—H (amines)	3300–3500
O—H (alcohols)	3230–3550 (broad)
C—H	2850–3300
O—H (acids)	2500–3000 (very broad)
C≡N	2220–2260
C=O	1680–1750
C=C	1620–1680
C—O	1000–1300
C—C	750–1100

^{13}C NMR chemical shift data

Type of carbon		δ/ppm
—C—C—		5–40
R—C—Cl or Br		10–70
R—C(=O)—C—		20–50
R—C—N		25–60
—C—O—	alcohols, ethers or esters	50–90
C=C		90–150
R—C≡N		110–125
		110–160
R—C(=O)—	esters or acids	160–185
R—C(=O)—	aldehydes or ketones	190–220

UV absorption

(This is not a definitive list and is approximate.)

Chromophore	λ_{max} (nm)
C—H	122
C—C	135
C=C	162

Chromophore	λ_{max} (nm)
C≡C	173 178 196 222
C—Cl	173
C—Br	208

NESA Number: ………………………………….

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

NESA Number: …………………………………….

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.
Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

NESA Number: ………………………………….

Ascham School

HSC CHEMISTRY

SEMESTER II EXAMINATION

Multiple Choice Answer Sheet

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

NESA Number: **Marking Guidelines**

Ascham School

2023 SEMESTER II EXAMINATION

Chemistry

MARKING GUIDELINES

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks

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

Section II – 80 marks

- Attempt Questions 21–36
- Allow about 2 hours and 25 minutes for this section

NESA Number: **Marking Guidelines**

Section I

20 marks
Attempt Questions 1-20
Allow about 35 minutes for this part

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

1. What is the measurement taken by an atomic absorption spectrometer?

   A. Absorbance

   B. Volume

   C. Density

   D. Mass

2. Ammonia is produced in the Haber process in the following reaction.

   $N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$

   Magnetite (Fe_2O_3) is a commonly used catalyst for this reaction. In an industrial setting, what will be the effect of magnetite on the equilibrium concentration of hydrogen gas?

   A. A decrease in the rate of reaction

   B. An increase in the rate of reaction

   C. No effect on the concentration of hydrogen gas

   D. A decrease in the concentration of hydrogen gas

3. During crewed space flight, carbon dioxide is removed from the air by "CO_2 scrubbers" containing solid lithium hydroxide. Two relevant equations are:

   $LiOH(s) + H_2O(g) \rightarrow LiOH.H_2O(s)$ $\Delta H = -61.27$ kJ/mol

   $Li_2CO_3(s) + 3H_2O(g) \rightarrow 2LiOH.H_2O(s) + CO_2(g)$ $\Delta H = -28.18$ kJ/mol

   What is the overall ΔH for the scrubbing reaction:

   $2LiOH\,(s) + CO_2\,(g) \rightarrow Li_2CO_3(s) + H_2O(g)$

   A. −33.09 kJ/mol

   B. −84.45 kJ/mol

   C. −94.36 kJ/mol

   D. −178.9 kJ/mol

4. The equilibrium constant for the reaction $Br_2(g) + I_2(g) \rightleftharpoons 2IBr(g)$ is Keq = 1.2×10^2 at 150°C.

   What is Keq for the reaction $4IBr(g) \rightleftharpoons 2Br_2(g) + 2I_2(g)$ at 150°C?

   A. 1.6×10^{-2}

   B. 4.1×10^{-3}

   C. 6.9×10^{-5}

   D. 8.03×10^{-5}

5. The four equations below represent different equilibrium systems.

Equation 1	$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$	$\Delta H = -180$ kJ mol^{-1}
Equation 2	$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$	$\Delta H = -46$ kJ mol^{-1}
Equation 3	$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$	$\Delta H = +93$ kJ mol^{-1}
Equation 4	$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$	$\Delta H = +205$ kJ mol^{-1}

   After equilibrium was established in each system, the temperature was decreased and the pressure was increased.

   In which equilibrium system would both changes result in an increase in yield?

   A. Equation 1

   B. Equation 2

   C. Equation 3

   D. Equation 4

6. Which reagents and conditions are best for converting propan-1-ol into propanoic acid?

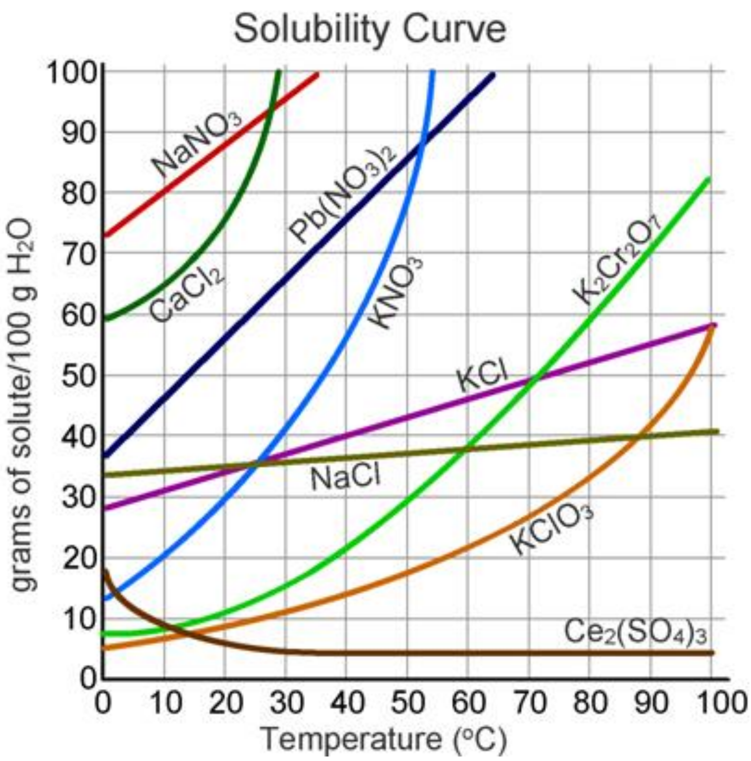
   A. Reflux with a metal catalyst

   B. Sunlight with bromine water

   C. Reacting with concentrated sulfuric acid

   D. Heat with acidified potassium dichromate

7. A solution was prepared by dissolving 70g of KNO_3 in 200 ml of water at 60°C. The solution was cooled to 10°C. How much KNO_3 will be deposited as a solid?



A. 15g

B. 25g

C. 30g

D. 50g

8. If Solution X has a pH of 3 and Solution Y has a pH of 6, we can conclude that:

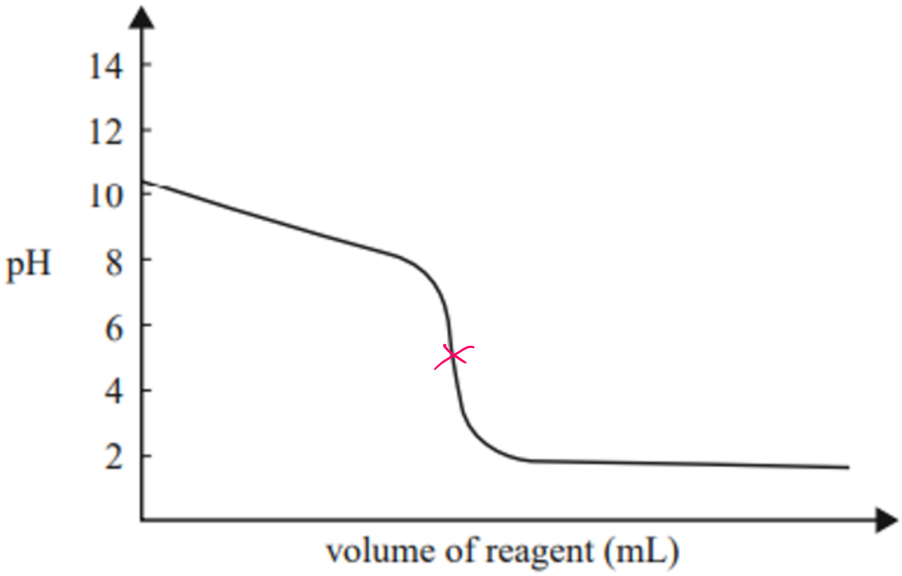
A. $[H^+]$ in Solution X is half that of $[H^+]$ in Solution Y

B. $[OH^-]$ in Solution Y is twice that of $[OH^-]$ in Solution X

C. Solution Y must contain a stronger acid than Solution X

D. $[H^+]$ in Solution X is 1000 times that of $[H^+]$ in Solution Y

9. The diagram below represents a titration curve for the reaction between a particular acid and a particular base.



Which of these equations best represents the reaction described in the titration curve?

A. HCl *(aq)* + NH_3 *(aq)* → NH_4Cl *(aq)*

B. HCl *(aq)* + NaOH *(aq)* → NaCl *(aq)* + H_2O (l)

C. CH_3COOH *(aq)* + NH_3 *(aq)* → CH_3COONH_4 *(aq)*

D. CH_3COOH *(aq)* + NaOH *(aq)* → CH_3COONa *(aq)* + H_2O (l)

10. What volume of 0.25 mol/L hydrochloric acid is required to react completely with 40 mL of 0.50 mol/L calcium hydroxide?

A. 40 mL

B. 80 mL

C. 120 mL

D. 160 mL

11. Which one of the following represents a conjugate acid-base pair?

A. N^{3-} / CN^-

B. NH_3 / NH_2^-

C. H_3PO_4 / PO_4^{3-}

D. CH_3CH_2OH / CH_3CHO

12. Which statement accurately describes the equivalence point in an acid-base titration?

   A. Indicator changes colour

   B. The pH of the solution is 7

   C. The volume of acid equals the volume of base

   D. The mole ratio of acid to base is equal to the stoichiometric ratio

13. One litre of an aqueous solution of potassium hydroxide has a pH of 12.0 at 25°C.
How many moles of solid potassium hydroxide must be added to raise the pH to 13.0?

   A. 10^{-13}

   B. 10^{-12}

   C. 0.09

   D. 0.10

14. H_2SO_4 and HNO_3 are both strong acids. CH_3COOH is a weak acid. 20.00 mL solutions of 0.10 mol/L concentrations of each of these acids were separately titrated with a 0.10 mol/L solution of NaOH. In order to react completely:

   A. all three acids will require the same amount of NaOH

   B. HNO_3 will require more NaOH than CH_3COOH but less than H_2SO_4

   C. H_2SO_4 and HNO_3 will require the same amount of NaOH but CH_3COOH will require less

   D. CH_3COOH and HNO_3 will require the same amount of NaOH but H_2SO_4 will require more

15. What is produced when 1-chlorobutane is treated with aqueous sodium hydroxide solution?

   A. butane

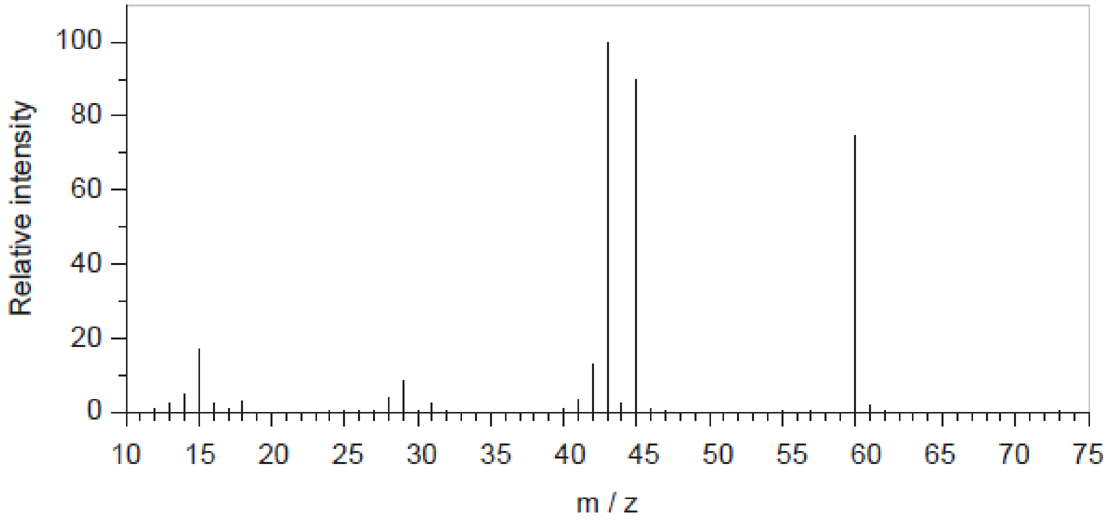
   B. butanal

   C. butan-1-ol

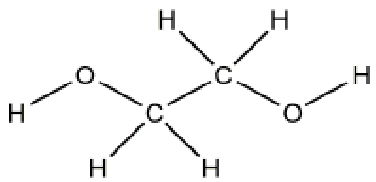
   D. butanoic acid

NESA Number: **Marking Guidelines**

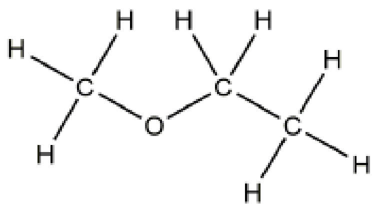
16. Which compound produces this mass spectrum?



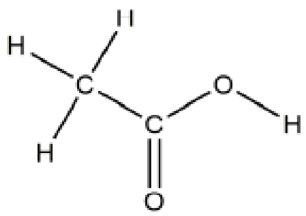
A.



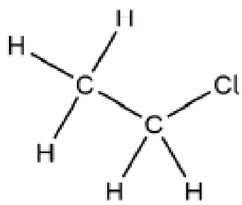
B.



C.

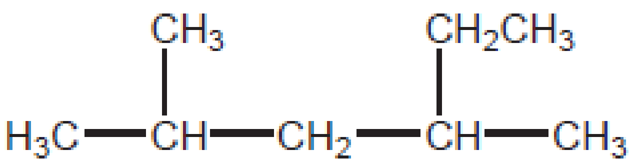


D.



Answer C

17. What is the IUPAC name of the molecule shown?



A. 2,4-dimethylhexane

B. 3,5-dimethylhexane

C. 2-methyl-4-ethylpentane

D. 2-ethyl-4-methylpentane

NESA Number: **Marking Guidelines**

18. What is the ratio of areas under each signal in the ^{1}H NMR spectrum of 2-methylbutane?

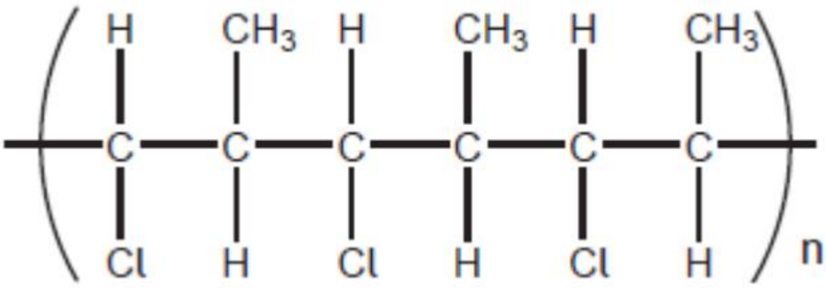
A. 6 : 1 : 5

B. 6 : 1 : 2 : 3

C. 3 : 3 : 1 : 5

D. 3 : 3 : 1 : 2 : 3

19. Which monomer forms the polymer shown?



A. $(CH_3)_2CHCl$

B. $CH(Cl) = CH(CH_3)$

C. $CH_2 = CH(Cl)$

D. $CH_2 = C(Cl)CH_3$

20. Cellulose is a condensation polymer formed from the glucose monomer $C_6H_{12}O_6$.
What would be the molar mass of a cellulose polymer made from 125 monomer units?

A. 20267.5g

B. 20285.5g

C. 22501.5g

D. 22519.5g

NESA Number: **Marking Guidelines**

Section II. Answer Booklet

80 marks
Attempt Questions 21 - 36
Allow about 2 hours and 25 minutes for this section

Question 21. (2 marks) SG

NO_2 reacts to form N_2O_4 as follows:

$$2NO_2\,(g) \rightleftharpoons N_2O_4\,(g) \qquad \Delta H = -57.2 \text{ kJ/mol}$$

Outline what happens to the enthalpy (ΔH) and entropy (ΔS) as this system is cooled.

…………………………………………………………………………………………………

The enthalpy change (ΔH) remains constant (since energy can leave or enter the system).

As the system is cooled, the reaction moves toward products. The product side has fewer molecules so the entropy decreases. Entropy also reduces because cooling results in a reduction of molecular motion and a decrease in the number of accessible microstates for the molecules

Question 22. (3 marks) DB

Qualitatively compare the solubility of lead (II) chloride in water with its solubility in a solution of sodium chloride. Include an equation in your answer.

Makes correct statement = 1, refers to common ion effect = 1 some relevant explanation = 1

Sample answer Lead chloride will be more soluble in water than in sodium chloride. This is due to the common ion effect. When dissolving lead chloride in a solution of NaCl there are already some common ions (the chloride) present and this results in the PbCl2 being less soluble

…………………………………………………………………………………………………

Marker comments – done well by most. Some did a lot of calculation – not asked for. A few did not include equation that is asked for

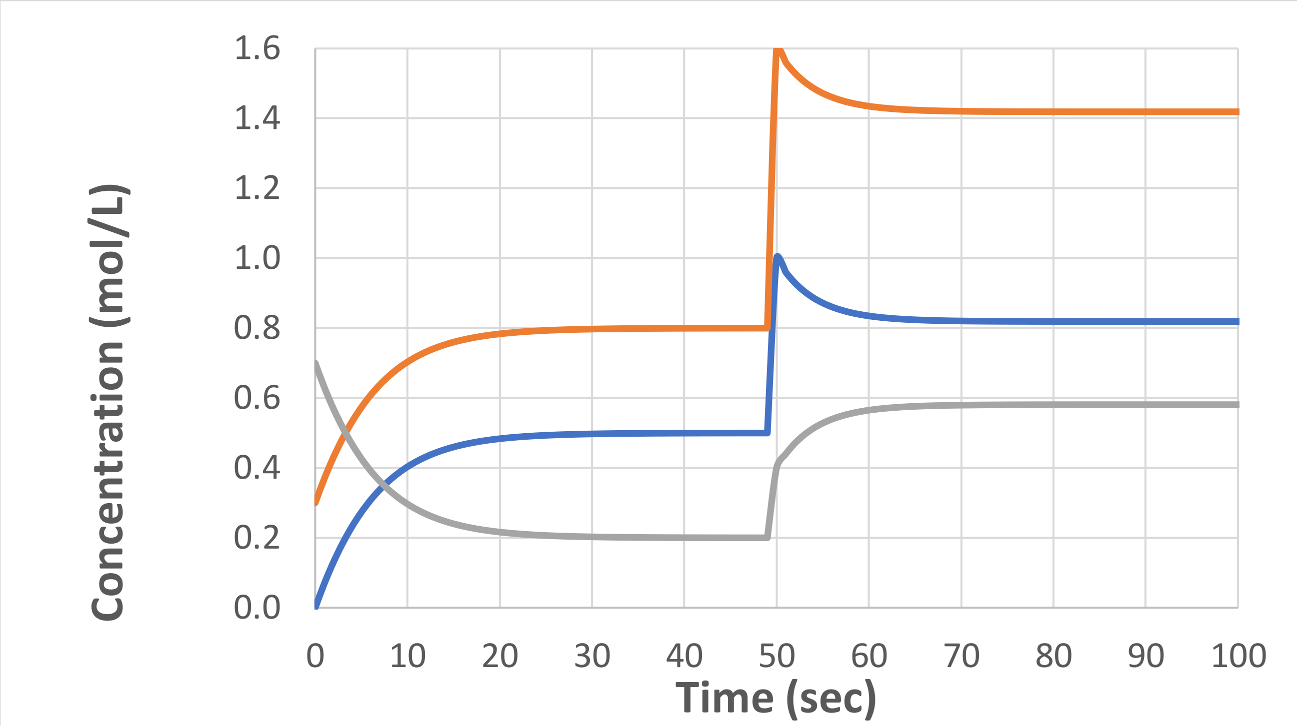
NESA Number: **Marking Guidelines**

Question 23. (5 marks) AB

Below is the concentration-time graph for the following reaction system:

$$CO\ (g) + Cl_2\ (g) \rightleftharpoons COCl_2\ (g) \qquad \Delta H = -220\ kJ/mol$$

At time = 0 seconds, there was no CO gas present in the system.



a) Calculate the equilibrium constant at 40 seconds. 2

$$K_{eq} = \frac{0.2}{0.5 \times 0.8}$$

$$= 0.5$$

Correct calculation showing working 2

Any relevant information 1

b) At 50 seconds the volume of the system was halved, keeping the temperature constant. Continue the graph to show how this change would affect the reaction system and how the system would respond to this change until equilibrium is restored. 3

1 mk showing proportionate change

1 mk COCl2 increasing, the other 2 decreasing

1 mk 1:1:1

NESA Number: **Marking Guidelines**

……

Question 24. (4 marks) SG

Water gas, a mixture of carbon monoxide, hydrogen and oxygen, can react in the following exothermic reaction.

$$H_2\,(g) + CO\,(g) + O_2\,(g) \rightleftharpoons CO_2\,(g) + H_2O\,(g)$$

Use collision theory to explain how the following changes would affect this equilibrium.

a) a decrease in temperature 2

Since the reaction is exothermic, LCP predicts that the reaction will shift toward products to produce more heat. But now you have to justify that with collison theory. Since molecules are colliding with reduced energy, the rate of both forward and reverse reactions decrease but the reverse rate decreases more since the activation energy is higher for the endothermic direction

b) a decrease in the pressure 2

…When there is a decrease in pressure, the number of collisions between molecules decreases, decreasing the reaction rate. This decreases the forward reaction more than reverse reaction since the forward requires three molecules to collide (rare) while the reverse only requires two molecules to collide (not so rare))

Question 25. (3 marks) SG

Formic acid (HCO_2H) has a pKa of 3.77. What would be the pH of a 0.250M solution of this acid?

pKa = 3.77 so Ka = $10^{-3.77}$ = 1.698 x 10^{-4}

Ka = $[HCO_2^-][H^+] / [HCO_2H]$ = $x^2/(0.250-x)$ simplifies to $x^2/0.250$ if we assume that x is negligible compared to 0.250 (state this assumption in exam – not penalized here!!)

x = $\sqrt{}$ (1.698 x 10^{-4} x 0.250) = 0.006516 mol/L

pH = -log(x) = 2.19

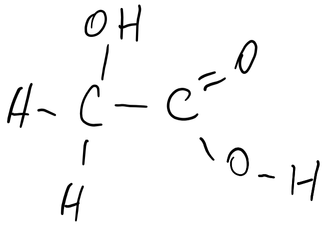
Many students did not write correct Ka expression.

NESA Number: **Marking Guidelines**

Question 26. (6 marks) AB

Glycolic acid $CH_2(OH)COOH$, is used in some skincare products.

a) Draw the structural formula of glycolic acid. **1**



b) The equation for the neutralisation of glycolic acid is

$CH_2(OH)COOH\ (aq) + H_2O\ (l) \rightleftharpoons CH_2(OH)COO^-\ (aq) + H_3O^+\ (aq)\quad K_a = 1.48 \times 10^{-4}$

Sodium glycolate, $CH_2(OH)COONa$, is a soluble salt of glycolic acid.

How does the pH of a solution of glycolic acid change when some solid sodium glycolate is dissolved in the solution? Justify your answer. **2**

Adding more Naglyc shifts the equilibrium to the left

Therefore pH increases as there are less hydronium ions

…………………………………………………………………………………………………

…Referring to less H3O+ and increasing pH ----- 2

Any relevant information 1………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

100 mL of a 1.00 mol/L solution of glycolic acid is spilt on the floor. This could be neutralized by sodium carbonate. The equation for this reaction is shown below:

$Na_2CO_3\ (s) + 2CH_2(OH)COOH\ (aq) \rightarrow 2CH_2(OH)COONa\ (aq) + H_2O\ (l) + CO_2\ (g)$

c) What is the minimum mass of sodium carbonate that should be used to neutralise the spill? **3**

$n = CV = 100 \times 10^{-3} \times 1.00 = 0.1$ mol (glyc acid)

$n_{Na_2CO_3} = 0.1 \div 2$

$= 0.05 \times FM\ (105.99)$

$m = 5.2995$

$= 5.3$ g

NESA Number: **Marking Guidelines**

Question 27. (5 marks) AB

a) A buffer of carbonate (CO_3^{2-})/hydrogencarbonate (HCO_3^-) is present in blood plasma to maintain a pH between 7.35 and 7.45. Write an equation to show the relevant species in this buffer solution. 2

$HCO_3^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons CO_3^{2-}{}_{(aq)} + H_3O^+{}_{(aq)}$

Correct equation with states 2

Any relevant information 1

b) Explain why 300.0 mL of 1.00 mol/L carbonate/hydrogencarbonate buffer does not change in pH significantly when 3 drops of 1.00 mol/L HCl are added to it, yet when 3 drops of 1.00 mol/L HCl are added to 300.0 mL of distilled water there is a significant change in pH. 3

$H_2O + HCl \longrightarrow H_3O^+ + Cl^-$

lowers pH

Buffer adding HCl causes equilibrium to shift to the LHS ~~re~~moving H_3O^+ & maintaining pH

Explaining buffer and water – 3 marks

Description and water OR only explaining buffer 2 marks

Any relevant information 1 mark

Question 28. (4 marks) DB

In a beaker 12.00 mL of 0.033 mol/L sulfuric acid solution is added to 32.50 mL of 0.0288 mol/L potassium hydroxide solution. Calculate the pH of the resulting solution. 4

nH_2SO_4 = cv = 0.012 x 0.033 = 0.000396 so nH+ = 0.000792mol

nKOH = cv = 0.0325 x 0.0288 = 0.000936 mol so OH in excess of 0.000936 - 0.000792 = 0.000144

mol in 44.5 mls so [OH-] = n/v = 0.0032359 mol/L

pOH = -log [OH] = 2.49 so pH = 11.51

All correct = 4 marks

Calculate n H+ = 1 mk

Calc OH = 1 mk

Identify OH in excess = 1 mk

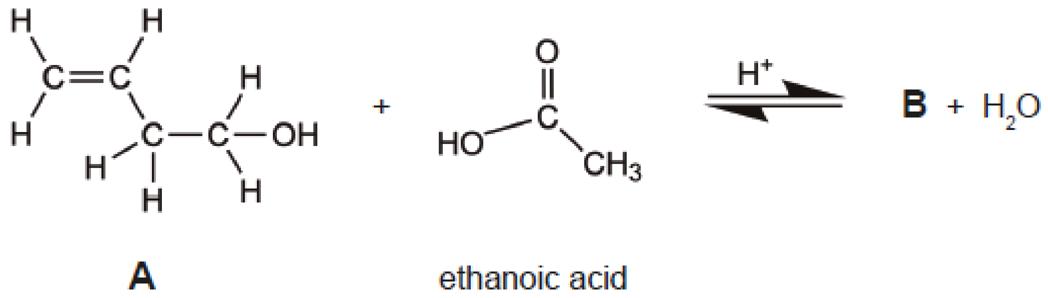
Calc pH = 1 mk

Marker comments – some students referred to the pOH as the pH but this question generally done well

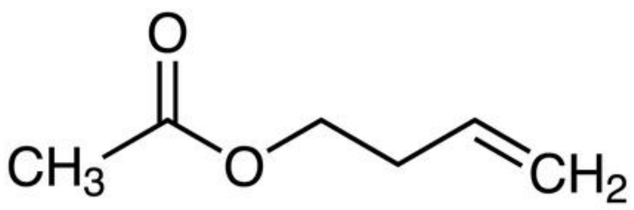
NESA Number: **Marking Guidelines**

Question 29. (9 marks) SG

An organic compound, **A**, reacts with ethanoic acid to produce **B** using concentrated sulfuric acid as a catalyst. 3



a) Draw the structural formula of B. 1



b) Justify, with reference to Le Châtelier's principle, a method to increase the amount of compound B produced. 2

Increase concentrations of one or both reactants, decrease concentrations of one or both products.

LCP says reaction will move to the right to counter any of those changes.

Not temperature: we have no information about whether it is exo or endothermic. Pressure – all in liquid state, so pressure not effective.

c) Explain, with reference to intermolecular forces, why compound B is more volatile than A. 2

The intermolecular bonds in alcohols are dispersion forces and H-bonds. H-bonds are relatively strong which lowers the volatility.

In contrast, esters have only dispersion forces and dipole-dipole intermolecular forces. While the dispersion forces are broadly similar, the dipole-dipole forces are weaker, meaning that the ester is more volatile.

Question 29 continues on the next page

d) Justify safety procedures that are needed in carrying out this reaction in a school Science laboratory. 4

You need to state the safety precaustion AND justify it!

Alcohols are flammable, so no flames – use mantle or heated water.

Liquid carboxylic acids are corrosive, avoid skin contact – glasses, gloves.

Concentrated sulfuric acid is corrosive, avoid skin contact – glasses, gloves.

Vapours are irritants, so perform reaction in a fume hood

Reflux: this is performed so the reaction proceeds not for safety

Question 30. (4 marks) AB

Describe two limitations of the Arrhenius theory of acids and bases and how the Bronsted-Lowry model overcomes these limitations.

…………………………………………………………………………………………………….

……Arrhenuis stated that acids ionize to form H+ ions and bases produce OH- ions.

This could not explain NH_3 as a base

His theory did not account for the role of the solvent. B-L accounts for acids and bases by referring to proton donation and proton acceptance and takes into account ammonia.

You could show equations.

2 limitations described showing how B-L overcomes both the limitations 4 marks

2 limitations described with only 1 B-L 3 marks

1 limitation and 1 B-L 2 marks

Any relevant info 1 mark

……………………………………………………………………………………………….

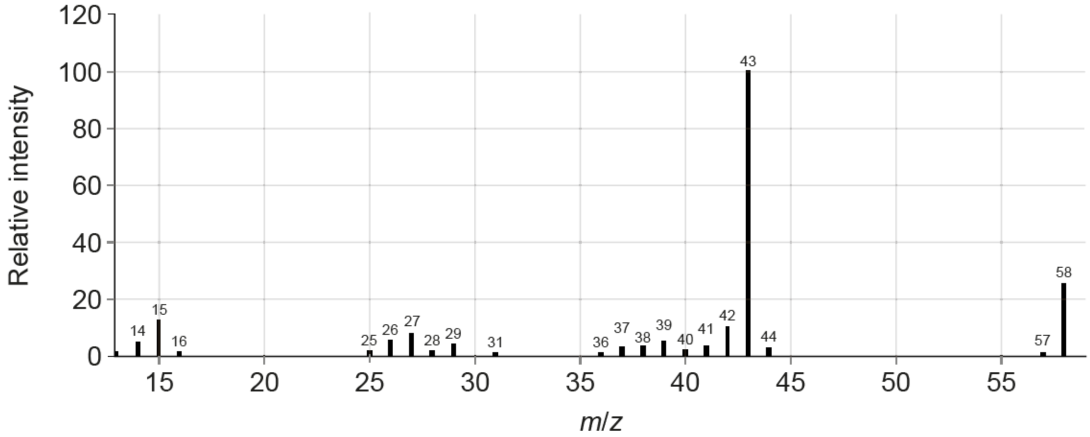
…………………………………………………………………………………………………….

NESA Number: **Marking Guidelines**

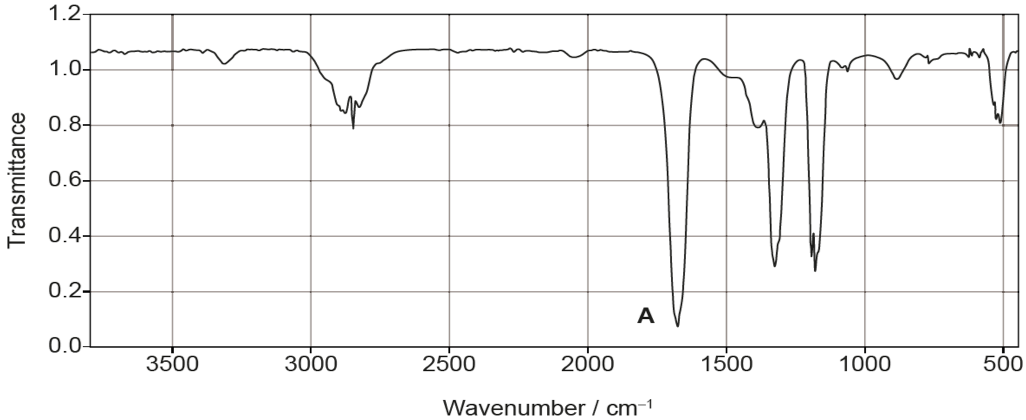
Question 31. (6 marks) DB

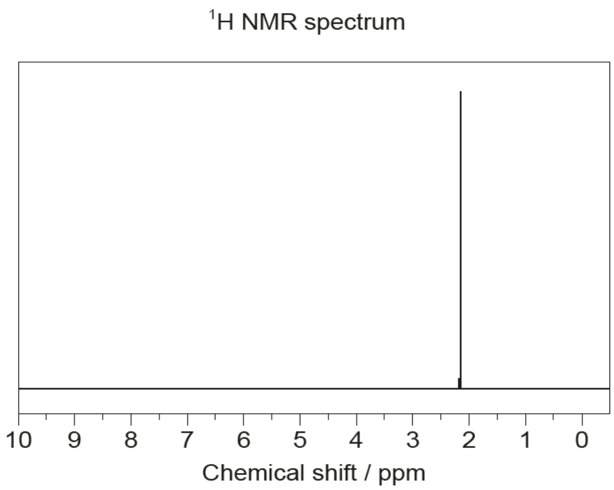
a) Combustion analysis of an unknown organic compound indicated that it contained only carbon, hydrogen and oxygen. Deduce the identity of the unknown compound using the information. 4

Mass spectroscopy



Infrared spectrum





Question 31 continues on the next page

Question 31 continued

Identify and draw propanone = 1 mark

Uses at least 1 piece of evidence from each set of data = 3 x 1 mk

e.g Mass spec – parent peak of 58 fits formula $C3H6O$

IR = peak at A around 1700 corresponds to C=O

H NMR – only one H environment so must be symmetrical structure

Marker comments – done very well by most.

b) Draw and name an isomer of the compound identified in part (a). 2

Propanal = 1 mk

correct structural formula = 1 mk

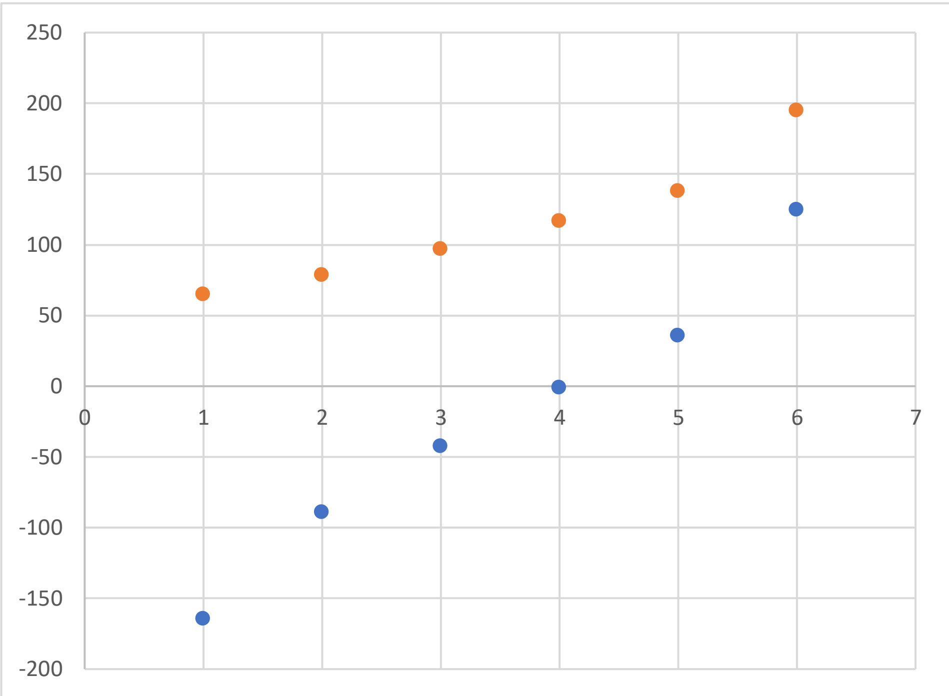
NESA Number: **Marking Guidelines**

Question 32. (7 marks) DB

The following data shows the boiling points of primary alcohols and alkanes.

Alkane	Boiling point (°C)	Alcohol	Boiling point (°C)
methane	-164	methanol	65
ethane	-89	ethanol	79
propane	-42	1-propanol	97
butane	-1	1-butanol	117
pentane	36	1-pentanol	138
octane	125	1-octanol	195

Graph the data on the grid below and explain the trends in this data. 7



Question 32 continues on the next page

NESA Number: **Marking Guidelines**

Question 32 continued

Graph – max 3 marks

Axes correct and labelled = 1 mk

Points plotted accurately – 1 mk

Lines appropriate and labelled – 1 mk

Trends – TWO needed

For each trend – state trend and give explanation = 2 marks

e.g. BP increases with chain length – larger number of dispersion forces

Alcohols greater than alkanes – presence of a Hydrogen bond in alcohols

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….

Marker comments – done well by most.Graphs were done very well with only a few getting scale wrong by not leaving space for 6 and 7 C species. Allowed either curved or straight lines

NESA Number: **Marking Guidelines**

Question 33. (4 marks) SG

Sulfur trioxide, SO_3, is made by the reaction of sulfur dioxide, SO_2, and oxygen, O_2, in the presence of a catalyst, according to the equation below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H < 0$$

In a closed system in the presence of the catalyst, the reaction achieves equilibrium at 1000K.

A mixture of 2.00 mol of $SO_2(g)$ and 2.00 mol of $O_2(g)$ was placed in a 4.00 L evacuated, sealed vessel and kept at 1000 K until equilibrium was reached. At equilibrium, the vessel was found to contain 1.66 mol of $SO_3(g)$.

Calculate the equilibrium constant, Keq, at 1000K.

Convert moles to moles/L – divide all by 4

	2SO2	O2	2SO3
I	0.5	0.5	0
C	-0.415	-0.415/2	+0.415
E	0.085	0.2925	0.415

$Keq = [SO_3]^2 / [SO_2]^2.[O_2] = 0.415^2/(0.2925 \text{ x } .085^2)$

$=81.5$ 3 sig figs

NESA Number: **Marking Guidelines**

Question 34. (5 marks) SG

A student is given 1 L of a 0.01 mol/L solution of calcium chloride.

a) How many grams of solid KOH will have to be added before a precipitate is formed (assume that the addition of KOH does not change the volume of the solution)? 3

Ca^{2+} (*aq*) + $2OH^-$(*aq*) $\rightleftharpoons$ $Ca(OH)_2$(*aq*) Ksp = 5.02×10^{-6}

A precipitate is formed when Ksp =$[Ca^{2+}][OH^-]^2$

Using $[Ca^{2+}]$ = 0.01mol/L , $[OH^-] = \sqrt{(5.02 \times 10^{-6}/0.01)}$ = 0.022405 mol/L

g of KOH = mol x FM = 0.022405 * (39.10+16+1.008) = 1.26g = 1 g

Incorrect approach: use the equation above with molar values assumes all $Ca(OH)_2$ precipitates (this gives an answer of 1.12g). The does not account for the small amount of $Ca(OH)_2$ that remains dissolved at Ksp.

b) What will be the pH of the solution immediately before the precipitate starts to form? 2

As a precipitate forms, $[OH^-]$ = 0.022405 mol/L, pOH= -log(0.022405) = 1.6496

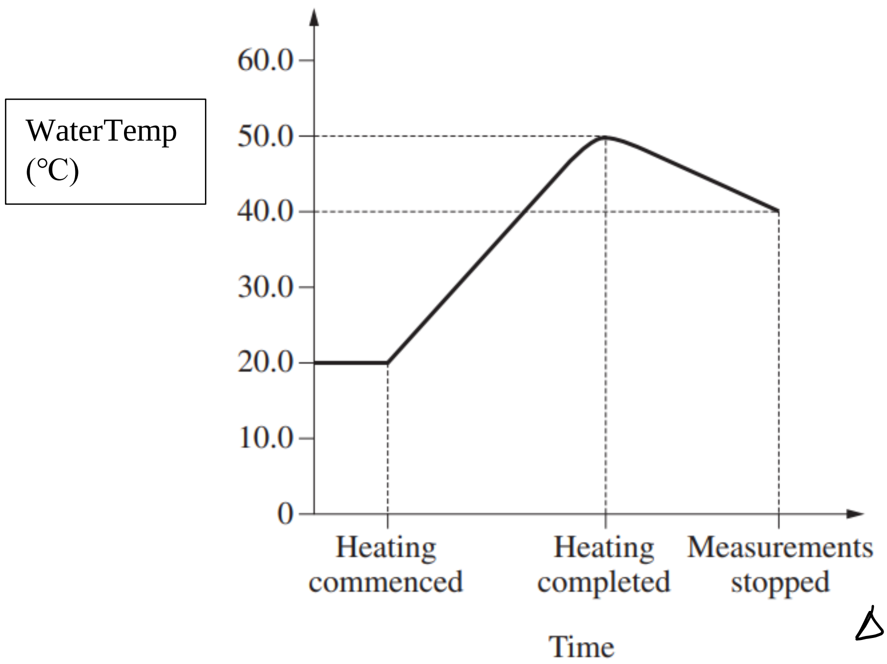
pH = 14 – pOH = 12.35

……………………………………………………………………………………………………….

NESA Number: **Marking Guidelines**

Question 35. (5 marks) AB

A student wanted to calculate the heat of combustion of butane. They used a spirit burner containing butane to heat up a 120g container of water and the following graph of temperature change was obtained.



$\Delta T = 30°C$

$\Delta = 0.513g$

At the start of the experiment the weight of the spirit burner was 373.156g and weighed 372.643g at the end of the experiment.

The theoretical molar heat of combustion for butane is $\Delta H_{comb} = -2877$ kJ/mol.

Explain, using quantitative data from your calculations, the reasons for the percentage difference between the experimental and theoretical values and suggest ways that this difference could be minimized.

$q = 120 \times 4.18 \times 30$
$= 15048 J$
$= 15.048 kJ$

C_4H_{10}
$n = \frac{0.513}{58.12}$
$= 0.0088$

$\Delta H_{exp} = \frac{15.048}{0.0088}$
$= 1704$ kJ/mol exothermic

Heat loss to the environment
Incomplete combustion

NESA Number: **Marking Guidelines**

To improve results – contain the equipment with a shield so the water absorbs all the heat

cannot say styrofoam for combustion

Calculation correct and explanation of heat loss and how to improve 5

Substantially correct calculation and explanation 4

Some calculation and an outline 3

Attempt at calculation 2

Any relevant information 1…

NESA Number: **Marking Guidelines**

Question 36. (6 marks) DB

Rain with a pH of less than 4.4 is classified as acid rain. Acid rain forms when acidic oxides such as SO_2 dissolve in rainwater to form sulfuric acid.

A 100.0 mL sample of rainwater was collected and diluted to 250 mL with distilled water. 25.0 mL aliquots of diluted rainwater were used in the titration with standardised sodium hydroxide solution.

The sodium hydroxide was standardised against a 3.76 x 10^{-5} mol/L HCl solution. An average titre of 21.3 mL of this acid was required to neutralise 25.0 mL aliquots of NaOH solution.

When the standardised NaOH solution was titrated with the diluted rainwater the following results were obtained.

Titre volume of NaOH (mL)				Average titre volume (mL
Trial 1	Trial 2	Trial 3	Trial 4	
21.81	19.64	19.67	19.66	19.65 or 66

Calculate the pH of the undiluted rainwater sample. Determine if it would be classified as acid rain or not.

Standard sol^n $n\,HCl = cv = 3.76 \times 10^{-5} \times 0.0213 = 8.0088 \times 10^{-7}$ mol

$= n\,NaOH$

$[NaOH] = \frac{n}{v} = 3.2035 \times 10^{-5}$ mol L^{-1}

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

$n\,NaOH = cv = 3.2035 \times 10^{-5} \times 0.01966 = 6.2981 \times 10^{-7}$

$n\,H_2SO_4 = \frac{n\,NaOH}{2} = 3.149 \times 10^{-7}$ in 25 mLs

$\therefore$ in 250 mLs 3.149×10^{-6} mol

$c\,H_2SO_4$ in 100 mLs $= \frac{n}{0.1} = 3.149 \times 10^{-5}$

$c\,H^+ = 2 \times 3.149 \times 10^{-5} = 6.2981 2 \times 10^{-5}$ mol/L

$pH = -\log 6.29... \times 10^{-5}$

$= 4.2$

$\therefore$ is acid rain

Approp eqn = 1

Standard sol^n - moles 1

- conc 1

correct avg 1

n NaOH/H_2SO_4 1

$[H^+]$ [pH] 1

Statement 1

End of paper

NESA Number: **Marking Guidelines**

Extra writing pages

2019 HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

FORMULAE SHEET

$n = \frac{m}{MM}$	$c = \frac{n}{V}$	$PV = nRT$
$q = mc\Delta T$	$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$	$\text{pH} = -\log_{10}[\text{H}^+]$
$pK_a = -\log_{10}[K_a]$	$A = \varepsilon lc = \log_{10}\frac{I_o}{I}$	

Avogadro constant, N_A .... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and
at 0°C (273.15 K) .... 22.71 L
at 25°C (298.15 K) .... 24.79 L

Gas constant .... 8.314 J mol^{-1} K^{-1}

Ionisation constant for water at 25°C (298.15 K), K_w .... 1.0×10^{-14}

Specific heat capacity of water .... 4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

Solubility constants at 25°C

Compound	K_{sp}
Barium carbonate	2.58×10^{-9}
Barium hydroxide	2.55×10^{-4}
Barium phosphate	1.3×10^{-29}
Barium sulfate	1.08×10^{-10}
Calcium carbonate	3.36×10^{-9}
Calcium hydroxide	5.02×10^{-6}
Calcium phosphate	2.07×10^{-29}
Calcium sulfate	4.93×10^{-5}
Copper(II) carbonate	1.4×10^{-10}
Copper(II) hydroxide	2.2×10^{-20}
Copper(II) phosphate	1.40×10^{-37}
Iron(II) carbonate	3.13×10^{-11}
Iron(II) hydroxide	4.87×10^{-17}
Iron(III) hydroxide	2.79×10^{-39}
Iron(III) phosphate	9.91×10^{-16}

Compound	K_{sp}
Lead(II) bromide	6.60×10^{-6}
Lead(II) chloride	1.70×10^{-5}
Lead(II) iodide	9.8×10^{-9}
Lead(II) carbonate	7.40×10^{-14}
Lead(II) hydroxide	1.43×10^{-15}
Lead(II) phosphate	8.0×10^{-43}
Lead(II) sulfate	2.53×10^{-8}
Magnesium carbonate	6.82×10^{-6}
Magnesium hydroxide	5.61×10^{-12}
Magnesium phosphate	1.04×10^{-24}
Silver bromide	5.35×10^{-13}
Silver chloride	1.77×10^{-10}
Silver carbonate	8.46×10^{-12}
Silver hydroxide	2.0×10^{-8}
Silver iodide	8.52×10^{-17}
Silver phosphate	8.89×10^{-17}
Silver sulfate	1.20×10^{-5}

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for this examination paper. Some data may have been modified for examination purposes.

Infrared absorption data

Bond	Wavenumber/cm^{-1}
N—H (amines)	3300–3500
O—H (alcohols)	3230–3550 (broad)
C—H	2850–3300
O—H (acids)	2500–3000 (very broad)
C≡N	2220–2260
C=O	1680–1750
C=C	1620–1680
C—O	1000–1300
C—C	750–1100

^{13}C NMR chemical shift data

Type of carbon		δ/ppm
—C—C—		5–40
R—C—Cl or Br		10–70
R—C(=O)—C—		20–50
R—C—N		25–60
—C—O—	alcohols, ethers or esters	50–90
C=C		90–150
R—C≡N		110–125
		110–160
R—C(=O)—	esters or acids	160–185
R—C(=O)—	aldehydes or ketones	190–220

UV absorption

(This is not a definitive list and is approximate.)

Chromophore	λ_{max} (nm)
C—H	122
C—C	135
C=C	162

Chromophore	λ_{max} (nm)
C≡C	173 178 196 222
C—Cl	173
C—Br	208

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

NESA Number: **Marking Guidelines**

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

NESA Number: **Marking Guidelines**

Ascham School

HSC CHEMISTRY

SEMESTER II EXAMINATION

Multiple Choice Answer Sheet

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