Student Number: ....

Ascham School

2021 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 21–35 • 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

1. In an equilibrium what is a role of a catalyst?

   A. It slows the rate of reaction

   B. It ensures the reaction is exothermic

   C. It moves the chemical equilibrium of a reaction in the forward direction

   D. It provides an alternative pathway for the reaction with a lower activation energy

2. A chemist performed an acid-base titration. The acid was in a burette and a pipette was used to deliver a known quantity of the base into a conical flask. Which of the following gives the final rinse solution for each of these pieces of equipment?

	Burette	Pipette	Conical Flask
A	acid	water	base
B	acid	base	Water
C	Water	Base	Water
D	water	water	base

3. Which one of the following is a biofuel?

   A. Ethanol produced from crude oil

   B. Ethanol produced from cellulose

   C. Propane produced from natural gas

   D. Electricity produced by hydropower

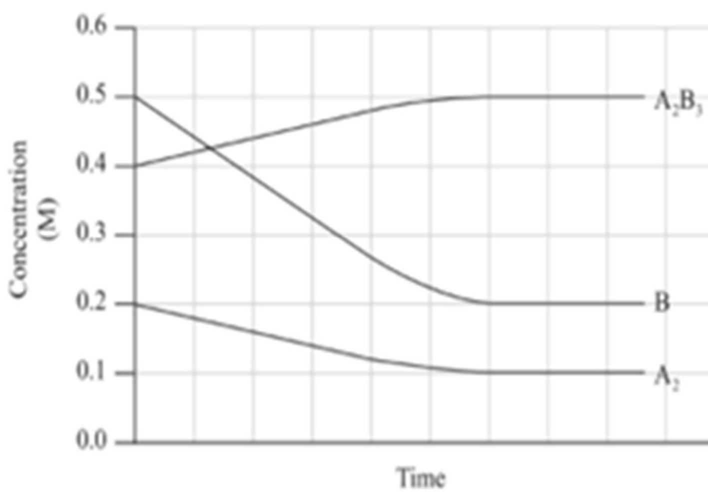
4. The equilibrium constants of four reactions are given below.

In which reaction does the equilibrium lie furthest to the left?

	Reaction	K_{eq}
A	$PCl_{3\,(g)} + Cl_{2\,(g)} \rightleftharpoons PCl_{5\,(g)}$	2.4×10^{1}
B	$AgIO_{3\,(s)} \rightleftharpoons Ag^{+}{}_{(aq)} + IO_3^{-}{}_{(aq)}$	3.0×10^{-8}
C	$Cl_{2\,(g)} + H_2O_{(l)} \rightleftharpoons HOCl_{(aq)} + Cl^{-}{}_{(aq)} + H^{+}{}_{(aq)}$	4.0×10^{-4}
D	$HSO_3^{-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^{+}{}_{(aq)} + SO_3^{2-}{}_{(aq)}$	6.3×10^{-8}

5. Consider the following gaseous reaction: $A_2 + 3B \rightleftharpoons A_2B_3$

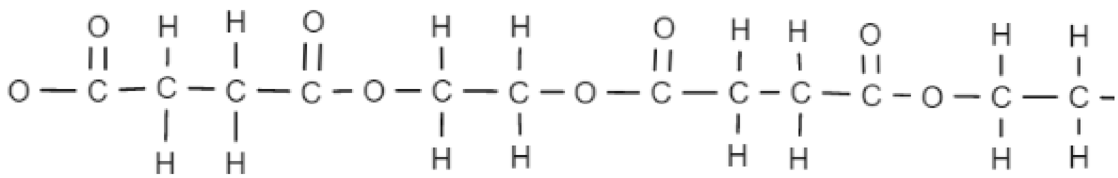
Quantities of all three chemicals are placed in a 1.0 L vessel at 1000 K and the system is allowed to come to equilibrium. The graph below indicates the changes in concentration with time.



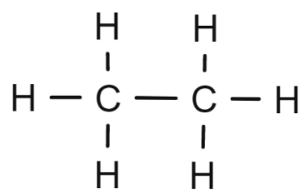
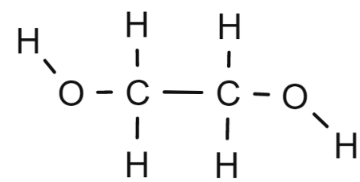
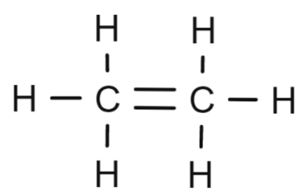
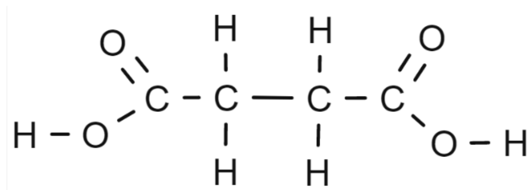
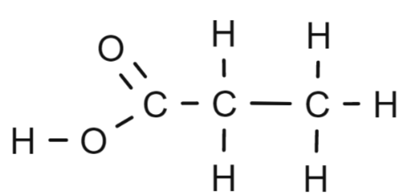
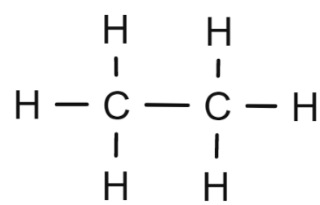
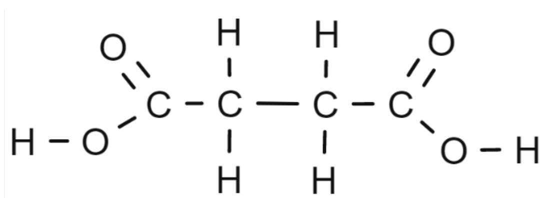
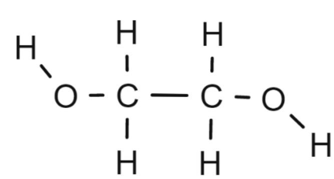
Which formula describes the equilibrium constant for the reaction at 1000 K?

A	$\dfrac{0.5}{0.1 \text{ x } 3(0.2)}$
B	$\dfrac{0.1 \text{ x } 3(0.2)}{0.5}$
C	$\dfrac{0.5}{0.1 \text{ x } (0.2)^3}$
D	$\dfrac{0.1 \text{ x } (0.2)^3}{0.5}$

6. PES (a polyester) is a is a condensation polymer. Part of the structure of the polymer is shown.



What are the two monomers of this polymer?

	Monomer 1	Monomer 2
A		
B		
C		
D		

7. Which is an example of an amphiprotic species?

   A. HPO_4^{2-}
   B. Al_2O_3
   C. CO_3^{2-}
   D. P_4O_{10}

8. 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	$CH_{4\,(g)} + 2O_{2\,(g)} \rightleftharpoons CO_{2\,(g)} + 2H_2O_{(g)}$	$\Delta H = -891$ 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

9. Lead could be separated from a mixture of $Pb(NO_3)_2(aq)$, $Ca(NO_3)_2(aq)$, $Cu(NO_3)_2(aq)$ and $Ba(NO_3)_2(aq)$ by precipitating with a room temperature solution of:

   A. sulfuric acid
   B. sodium chloride
   C. sodium carbonate
   D. sodium phosphate

10. The molar solubility of PbF_2 is 2.1×10^{-3} mol L^{-1}. What is its K_{sp}?

A. 8.1×10^{-2}
B. 8.8×10^{-6}
C. 3.7×10^{-8}
D. 9.3×10^{-9}

11. Which of these acids has the weakest conjugate base?

A. HCl
B. CH_3COOH
C. NH_4Cl
D. C_6H_5COOH

12. 10 ml of a 0.05 mol L^{-1} solution of sulfuric acid was diluted by making up to 1000 ml with distilled water. What was the pH of the resulting solution?

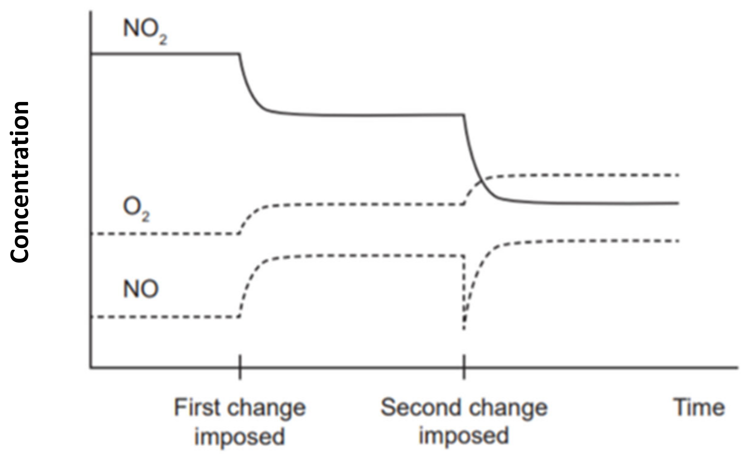
A. 2.0
B. 3.0
C. 3.3
D. 4.3

Questions 13 and 14 refer to the following information.

Nitrogen dioxide, $NO_{2\,(g)}$, is formed when nitrogen monoxide, $NO_{(g)}$, undergoes oxidation as shown below:

$2NO_{(g)} + O_{2\,(g)} \rightleftharpoons 2NO_{2\,(g)}$ $\Delta H = -62$ kJ mol^{-1}

A change was imposed on equilibrium gas mixture of NO, O_2 and NO_2 . The mixture returned to equilibrium and another change was imposed. The following graph shows the effects of the two changes.



13. What do the initial concentrations of the three gases indicate?

A. That the NO_2 gas reaches equilibrium first

B. That there is initially no NO gas present in the system

C. The relative proportions of the three gases are at equilibrium

D. That the O_2 and NO gases are producing NO_2 at a faster rate than they are being formed

14. Identify the changes that best account for the shape of the graph.

	First change	Second change
A	The temperature is decreased	The concentration of O_2 is increased
B	The temperature is decreased	The concentration of NO is decreased
C	The temperature is increased	The concentration of O_2 is increased
D	The temperature is increased	The concentration of NO is decreased

15. What volume of oxygen gas (at 25°C and 100kPa) would be required for the complete combustion of 16.0 grams of methanol?

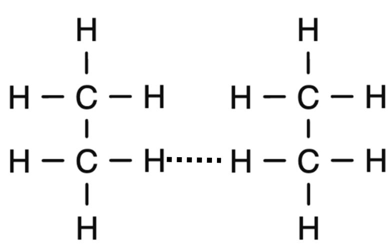
    A. 8.26 L
    B. 12.40 L
    C. 18.59 L
    D. 33.05 L

16. Which solution is basic at 25°C?

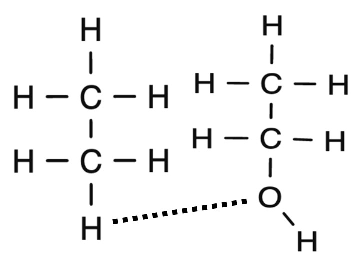
    A. solution of pH = 4.00
    B. $[H^+] = 1.0 \times 10^{-3}$ mol L^{-1}
    C. $[OH^-] = 1.0 \times 10^{-13}$ mol L^{-1}
    D. $[H_3O^+] = 1.0 \times 10^{-13}$ mol L^{-1}

17. In which one of the following pairs of molecules does the dotted line correctly show a hydrogen bond?

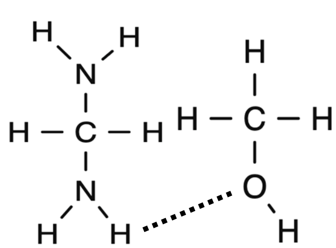
A.



B.

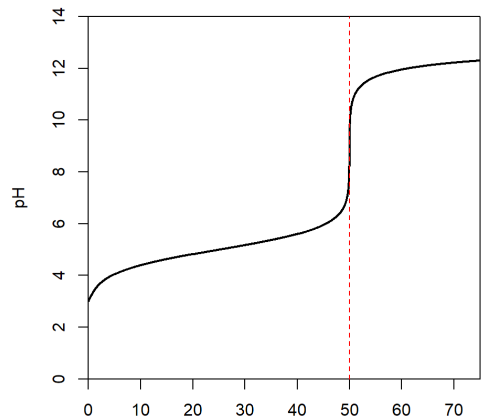


C.



D.

18. A student performed a titration using computer-based technology and the following graph was produced.



What can be deduced from the information in the graph?

A. The acid was a weak acid and the end point was at pH 9.
B. The acid was a strong acid and the end point was at pH 9.
C. The acid was a weak acid and the end point was at pH 2.5.
D. The acid was a strong acid and the end point was at pH 11.

19. An organic compound has the molecular formula, $C_4H_8O_2$. What is a possible name for this compound?

A. butanol
B. pentanoic acid
C. ethyl propanoate
D. propyl methanoate

20. How many structural isomers of the compound C_3H_9N?

A. 2
B. 3
C. 4
D. 5

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Section II. Answer Booklet

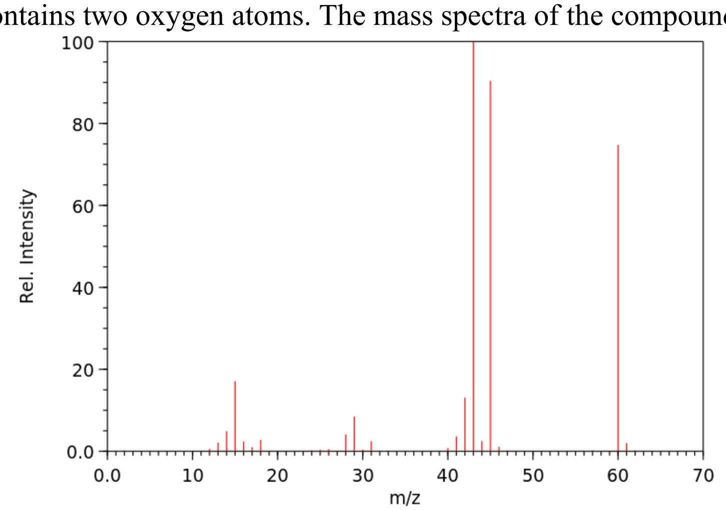
80 marks
Attempt Questions 21 - 34
Allow about 2 hours and 25 minutes for this section

Question 21. (2 marks)

Using a named example, explain how Aboriginal and Torres Strait Islander peoples have used solubility equilibria in their lives.

Question 22. (3 marks)

An organic compound is known to contain carbon, hydrogen and oxygen. It is also known that each molecule contains two oxygen atoms. The mass spectra of the compound is shown.



Use the information provided to identify the compound and justify your choice.

Question 23. (4 marks)

When magnesium chloride dissolves in water, changes occur in both the bonding and entropy. Explain these changes, supporting your answer with a labelled diagram.

Question 24. (5 marks)

(a) Which of lead (II) sulfate and lead (II) chloride is more soluble in water at 25°C. Give a reason for your answer. **2**

(b) Quantitatively compare the molar solubility of lead (II) sulfate in water with its solubility in a 0.10 mol L^{-1} solution of sodium sulfate at 25°C. **3**

Question 25. (8 marks)

Sulfur trioxide is made by the reaction of sulfur dioxide and oxygen in the presence of a catalyst. In a closed system the reaction quickly reaches equilibrium.

$$2SO_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2SO_{3\,(g)} \qquad \Delta H = -196 \text{ kJ mol}^{-1}$$

A mixture of 2.00 moles of $SO_{2\,(g)}$ and 2.00 moles of $O_{2\,(g)}$ was placed in a 4.00 L vessel and kept at 1000 K until equilibrium was reached. At equilibrium the vessel was found to contain 1.66 moles of $SO_{3\,(g)}$

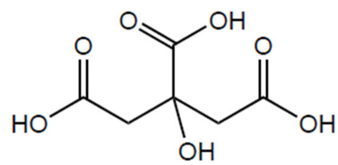
(a) Calculate the equilibrium constant, K_{eq}, at 1000 K **4**

A manufacturer of sulfur trioxide changes the reaction conditions used in part (a) in order to increase the percentage yield in a closed system where the volume may be changed if required.

(b) What changes would the manufacturer make to the system to increase the yield of $SO_{3\,(g)}$. Justify your answer. **4**

Question 26. (9 marks)

A molecule of citric acid, $C_6H_8O_7$, is shown.



The equation for the first dissociation of citric acid in water is

$$C_6H_8O_7\,(aq) + H_2O\,(l) \rightleftharpoons C_6H_7O_7^{-}\,(aq) + H_3O^{+}\,(aq)$$

a) Identify a conjugate acid–base pair in the equation. **1**

Acid	**Conjugate base**

$K_a = 5.01 \times 10^{-4}$ for the first dissociation constant at 298K.

b) Explain the strength of citric acid. Include the K_a expression in your answer. **3**

c) Citric acid and its conjugate base can be used as a buffer. Justify this statement. **5**

Question 27. (4 marks)

A student determined the concentration of an unknown solution of sulfuric acid using the following method:

Step 1: She weighed out 4.00 grams of sodium carbonate.

Step 2: She dissolved the sodium carbonate in a little distilled water and made it up to 1000 mL in a volumetric flask. This became her 0.10 mol L^{-1} standard solution.

Step 3: She then carried out a titration using 25.0 ml of the 0.10 mol L^{-1} sodium carbonate with the unknown sulfuric acid.

Bromothymol blue was the indicator.

Her results were recorded in the table below.

Titration	**Volume of sulfuric acid used mL)**
1	5.6
2	5.2
3	4.8

Assess the validity and reliability of this method and results. **4**

Question 28. (7 marks)

A conductivity graph can be used to determine sodium ion concentration in water samples.

A sample of water was collected from a bore (*i.e.* by drilling into an underground water reservoir). 10 mL of the sample was diluted with deionised water to a final volume of 1000 mL in a volumetric flask.

Six standard solutions containing a known concentration of sodium ions were also prepared.

Conductivities of the sample and standard solutions were determined. The results are shown in the table.

Na^+ concentration (ppm)	Conductivity
0	0
2	0.26
4	0.48
6	0.71
8	0.95
10	1.2

The bore sample had a conductivity of 0.78.

Based on taste, the following guidelines have been suggested for assessing the quality of drinking water.

- less than 2.6×10^{-2} mol/L of sodium is regarded as good quality drinking water.
- 2.6×10^{-2} to 3.9×10^{-2} mol/L of sodium is regarded as fair quality.
- 3.9×10^{-2} to 5.2×10^{-2} mol/L of sodium is regarded as poor quality.
- greater than 5.2×10^{-2} mol/L of sodium is regarded as unacceptable.

Question 28 continues on page 17

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Question 28 *(continued)*

By graphing the data in the table and performing relevant calculations, assess the suitability of the original bore water for use as drinking water.

Question 29. (6 marks)

A sample of white powder contained mostly magnesium oxide mixed with an unknown amount of an impurity. The impurity does not react with acid.

To determine the percentage purity of magnesium oxide in the white powder, 2.65 g of the powder was weighed out and reacted in 50 mL of 2.0 mol L^{-1} hydrochloric acid. The reaction mixture was then diluted with water to 250 mL in a volumetric flask.

Three samples of 25mL of the diluted reaction mixture were titrated against a standardised 0.10 mol L^{-1} solution of sodium hydroxide using a phenolphthalein indicator. The titre of sodium hydroxide used in the titrations is shown in the table.

Titration	**Volume NaOH (mL)**
1	17.2
2	15.5
3	15.4

Calculate the percent by mass of magnesium oxide in the white powder.

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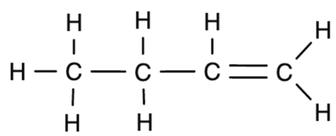
Question 30. (3 marks)

Water can be added to but-1-ene to form two products.

Complete the boxes to show the structural formulae for the products and identify a relevant catalyst. **3**



$+ H_2O \rightarrow$

Major product

Catalyst

Minor product

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Question 31. (7 marks)

The table shows the solubility of alcohols in water at 25°C

Formula	**Name**	**Solubility in Water (g/100ml)**
CH_3OH	1-methanol	Greater than 10
CH_3CH_2OH	1-ethanol	Greater than 10
$CH_3(CH_2)_2OH$	1-propanol	Greater than 10
$CH_3(CH_2)_3OH$	1-butanol	7.3
$CH_3(CH_2)_4OH$	1-pentanol	2.2
$CH_3(CH_2)_5OH$	1-hexanol	0.59
$CH_3(CH_2)_6OH$	1-heptanol	0.17
$CH_3(CH_2)_7OH$	1-octanol	0.03

a) Describe one procedure to ensure safe handling of these substances. **2**

b) Explain the trend in solubility in terms of intermolecular forces. **3**

c) 1-bromobutane will react with dilute sodium hydroxide. Name the products of this reaction. **2**

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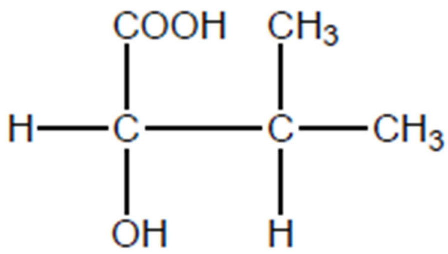
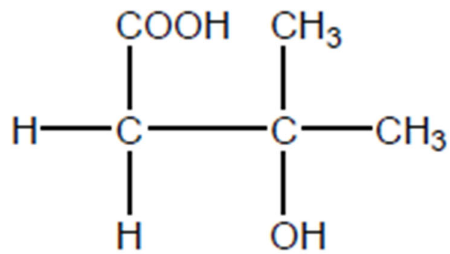
Question 32. (4 marks)

The structural formulas of two organic compounds are shown below.



A



B

A chemist needed to distinguish between these compounds.

Justify a test that could be used to distinguish the compounds and the result of that test. Include an equation in your answer.

Question 33. (5 marks)

An ester can be produced from two organic compounds and a catalyst.

Justify a procedure for the production of ethyl butanoate in a school laboratory. In your answer include the following:

- the structural formulae equation of this reaction;
- an explanation of the conditions and equipment needed to efficiently and safely carry out this reaction in the school laboratory; and
- a risk assessment.

Question 34. (6 marks)

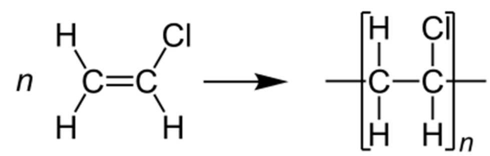
Ethene is a very important molecule extracted from fossil hydrocarbon sources. It is used as a starting molecule to produce polyvinylchloride (PVC). Initially it is converted to vinyl chloride, according to the following equation.

$$Cl_{2(g)} + C_2H_{4\,(g)} \rightarrow C_2H_3Cl_{(g)} + HCl$$

a) What is the IUPAC systematic name for vinyl chloride? **1**

b) How could you test that all the ethene had been converted to vinyl chloride? **2**

Vinyl chloride is then used to produce PVC



Assume n = 1200.

c) What volume of ethene measured at 25°C and 100kPa would be required to make 1.00 kilogram of PVC if the average molecular mass for PVC is 75.00 kg/mol? **3**

Question 35. (7 marks)

An experiment was conducted to find the heat of neutralisation in an acid-base reaction.

A solution was made by dissolving 3.79g of barium hydroxide in 100 mL of water. 30.0 mL of this barium hydroxide solution was reacted with 27.0 mL of a 0.400 mol L^{-1} solution of nitric acid. The heat of neutralisation was calculated to be 51.7 kJ mol^{-1} .

Calculate the temperature change and the resultant pH of the solution.

End of Paper

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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}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	Lead(II) hydroxide	1.43×10^{-15}
Calcium hydroxide	5.02×10^{-6}	Lead(II) phosphate	8.0×10^{-43}
Calcium phosphate	2.07×10^{-29}	Lead(II) sulfate	2.53×10^{-8}
Calcium sulfate	4.93×10^{-5}	Magnesium carbonate	6.82×10^{-6}
Copper(II) carbonate	1.4×10^{-10}	Magnesium hydroxide	5.61×10^{-12}
Copper(II) hydroxide	2.2×10^{-20}	Magnesium phosphate	1.04×10^{-24}
Copper(II) phosphate	1.40×10^{-37}	Silver bromide	5.35×10^{-13}
Iron(II) carbonate	3.13×10^{-11}	Silver chloride	1.77×10^{-10}
Iron(II) hydroxide	4.87×10^{-17}	Silver carbonate	8.46×10^{-12}
Iron(III) hydroxide	2.79×10^{-39}	Silver hydroxide	2.0×10^{-8}
Iron(III) phosphate	9.91×10^{-16}	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.

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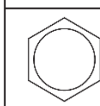
Infrared absorption data

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

Student Number: ……………………………………

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number Symbol Standard Atomic Weight Name	79 Au 197.0 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.

Student Number: ………………………………….

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

Student Number: ………………………………….

Ascham School

Marking guideline

2021 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 21–34
- Allow about 2 hours and 25 minutes for this section

Student Number: ……………………………………

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. In an equilibrium what is a role of a catalyst?

   A. It slows the rate of reaction

   B. It ensures the reaction is exothermic

   C. It moves the chemical equilibrium of a reaction in the forward direction

   D. It provides an alternative pathway for the reaction with a lower activation energy

2. A chemist performed an acid-base titration. The acid was in a burette and a pipette was used to deliver a known quantity of the base into a conical flask. Which of the following gives the final rinse solution for each of these pieces of equipment?

	Burette	Pipette	Conical Flask
A	acid	water	base
B	acid	base	Water
C	Water	Base	Water
D	water	water	base

3. Which one of the following is a biofuel?

   A. Ethanol produced from crude oil

   B. Ethanol produced from cellulose

   C. Propane produced from natural gas

   D. Electricity produced by hydropower

Student Number: ……………………………………

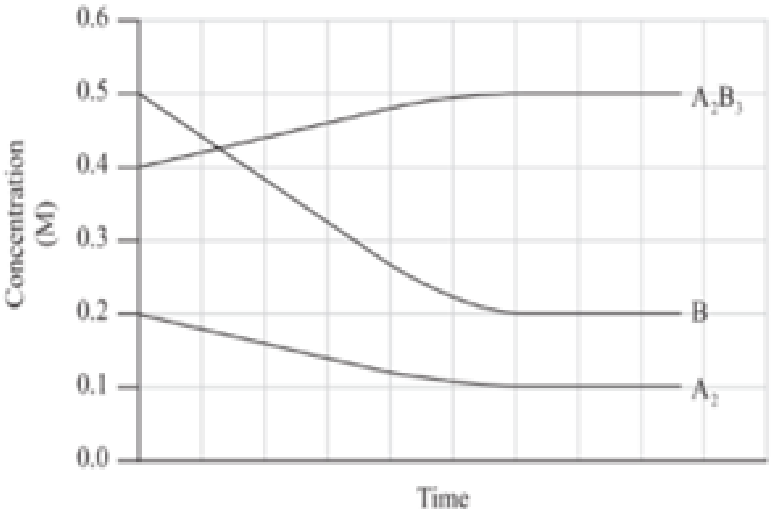
4. The equilibrium constants of four reactions are given below.

In which reaction does the equilibrium lie furthest to the left?

	Reaction	K_{eq}
A	$PCl_{3\,(g)} + Cl_{2\,(g)} \rightleftharpoons PCl_{5\,(g)}$	2.4×10^{1}
B	$AgIO_{3\,(s)} \rightleftharpoons Ag^{+}{}_{(aq)} + IO_3^{-}{}_{(aq)}$	3.0×10^{-8}
C	$Cl_{2\,(g)} + H_2O_{(l)} \rightleftharpoons HOCl_{(aq)} + Cl^{-}{}_{(aq)} + H^{+}{}_{(aq)}$	4.0×10^{-4}
D	$HSO_3^{-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^{+}{}_{(aq)} + SO_3^{2-}{}_{(aq)}$	6.3×10^{-8}

5. Consider the following gaseous reaction: $A_2 + 3B \rightleftharpoons A_2B_3$

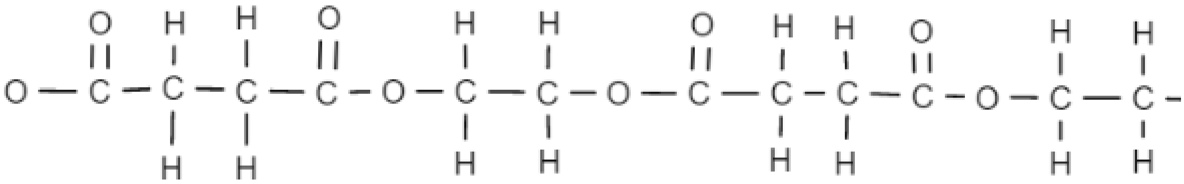
Quantities of all three chemicals are placed in a 1.0 L vessel at 1000 K and the system is allowed to come to equilibrium. The graph below indicates the changes in concentration with time.



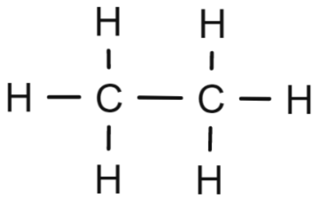
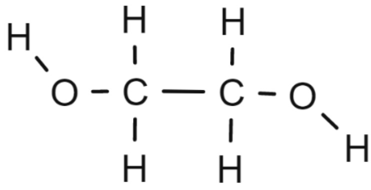
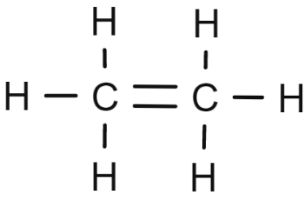
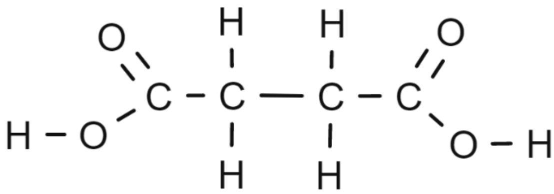
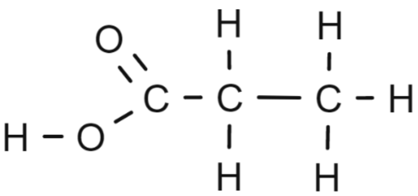
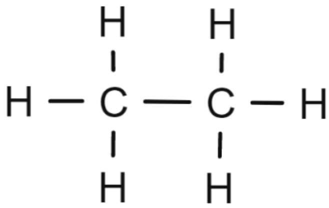
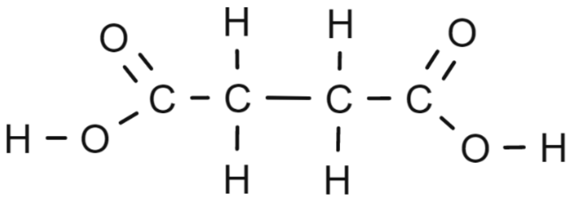
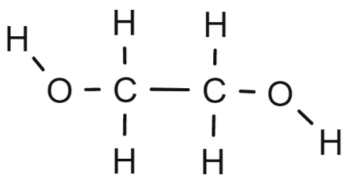
Which formula describes the equilibrium constant for the reaction at 1000 K?

A	$\frac{0.5}{0.1 \times 3(0.2)}$
B	$\frac{0.1 \times 3(0.2)}{0.5}$
C	$\frac{0.5}{0.1 \times (0.2)^3}$
D	$\frac{0.1 \times (0.2)^3}{0.5}$

6. PES (a polyester) is a is a condensation polymer. Part of the structure of the polymer is shown.



What are the two monomers of this polymer?

	Monomer 1	Monomer 2
A		
B		
C		
D		

7. Which is an example of an amphiprotic species?

A. Al_2O_3

B. CO_3^{2-}

C. P_4O_{10}

D. HPO_4^{2-}

A (changed order)

8. 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	$CH_{4\,(g)} + 2O_{2\,(g)} \rightleftharpoons CO_{2\,(g)} + 2H_2O_{(g)}$	$\Delta H = -891$ 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

9. Lead could be separated from a mixture of $Pb(NO_3)_2(aq)$, $Ca(NO_3)_2(aq)$, $Cu(NO_3)_2(aq)$ and $Ba(NO_3)_2(aq)$ by precipitating with a room temperature solution of:

A. sulfuric acid

B. sodium chloride

C. sodium carbonate

D. sodium phosphate

10. The molar solubility of PbF_2 is 2.1×10^{-3} mol L^{-1}. What is its K_{sp}?

A. 8.1×10^{-2}

B. 8.8×10^{-6}

C. 3.7×10^{-8}

D. 9.3×10^{-9}

11. Which of these acids has the weakest conjugate base?

A. HCl

B. CH_3COOH

C. NH_4Cl

D. C_6H_5COOH

12. 10 ml of a 0.05 mol L^{-1} solution of sulfuric acid was diluted by making up to 1000 ml with distilled water. What was the pH of the resulting solution?

A. 2.0

B. 3.0

C. 3.3

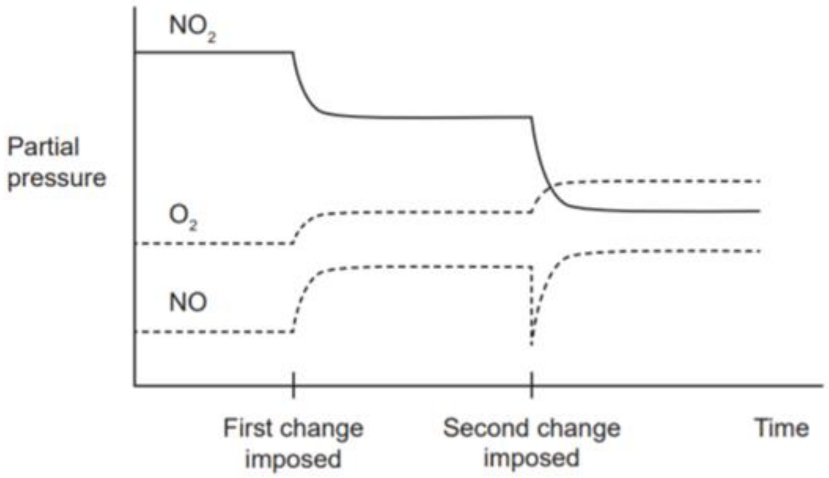
D. 4.3

Questions 13 and 14 refer to the following information.

Nitrogen dioxide, $NO_{2\,(g)}$, is formed when nitrogen monoxide, $NO_{(g)}$, undergoes oxidation as shown below:

$2NO_{(g)} + O_{2\,(g)} \rightleftharpoons 2NO_{2\,(g)}$ $\Delta H = -62\ kJ\ mol^{-1}$

A change was imposed on equilibrium gas mixture of NO, O_2 and NO_2. The mixture returned to equilibrium and another change was imposed. The following graph shows the effects of the two changes.



13. What do the initial concentrations of the three gases indicate?

A. That the NO_2 gas reaches equilibrium first
B. That there is initially no NO gas present in the system
C. The relative proportions of the three gases are at equilibrium
D. That the O_2 and NO gases are producing NO_2 at a faster rate than they are being formed

14. Identify the changes that best account for the shape of the graph.

	First change	Second change
A	The temperature is decreased	The concentration of O_2 is increased
B	The temperature is decreased	The concentration of NO is decreased
C	The temperature is increased	The concentration of O_2 is increased
D	The temperature is increased	The concentration of NO is decreased

15. What volume of oxygen gas (at 25°C and 100kPa) would be required for the complete combustion of 16.0 grams of methanol?

A. 8.26 L

B. 12.40 L

C. 18.59 L

D. 33.05 L

16. Which solution is basic at 25°C?

A. solution of pH = 4.00

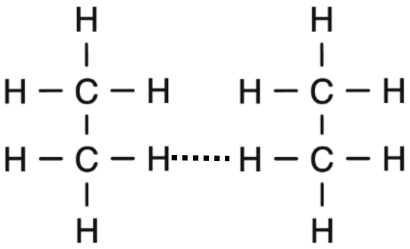
B. $[H^+] = 1.0 \times 10^{-3}$ mol L^{-1}

C. $[OH^-] = 1.0 \times 10^{-13}$ mol L^{-1}

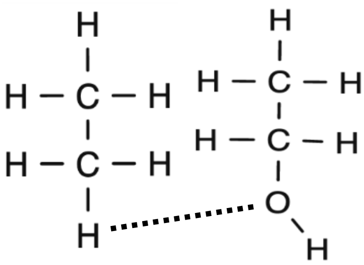
D. $[H_3O^+] = 1.0 \times 10^{-13}$ mol L^{-1}

17. In which one of the following pairs of molecules does the dotted line correctly show a hydrogen bond?

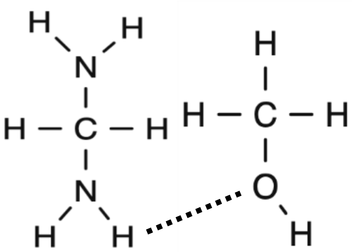
A.



B.

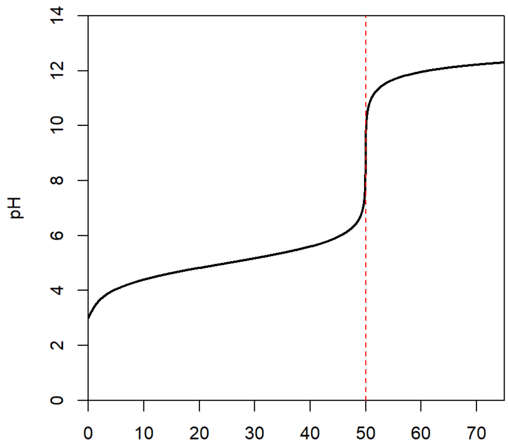


C.



D.

18. A student performed a titration using computer-based technology and the following graph was produced.



What can be deduced from the information in the graph?

A. The acid was a weak acid and the end point was at pH 9.
B. The acid was a strong acid and the end point was at pH 9.
C. The acid was a weak acid and the end point was at pH 2.5.
D. The acid was a strong acid and the end point was at pH 11.

19. An organic compound has the molecular formula, $C_4H_8O_2$. What is a possible name for this compound?

A. butanol
B. pentanoic acid
C. ethyl propanoate
D. propyl methanoate

20. How many structural isomers of the compound C_3H_9N?

A. 2
B. 3
C. 4
D. 5

Student Number: ....

Section II. Answer Booklet

80 marks
Attempt Questions 21 - 34
Allow about 2 hours and 25 minutes for this section

Question 21. (2 marks)

Using a named example, explain how Aboriginal and Torres Strait Islander peoples have used solubility equilibria in their lives.

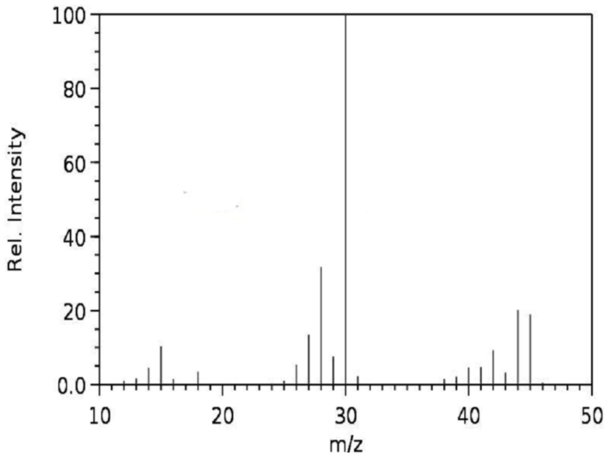
Criteria	Marks
Uses solubility equilibria to explain appropriate example	2
Provides some relevant information	1

Sample answer

Cycads are a food source but contain toxins (cycasin). Because these are soluble they can be removed by soaking in flowing water – the toxin is dissolved and constantly removed so no =bm established

Question 22. (3 marks)

An organic compound is known to contain carbon, nitrogen and hydrogen. It's mass spectra is shown below.



changed

Use the information provided to identify the compound and justify your choice.

Criteria	Marks
*Identifies compound *Gives molecular or structural formula *Gives reason for choice	3
Two of above	2

Criteria	Marks
One of above	1

Sample answer

From data – 60 = molar mass/formula mass has to contain 2 X O

So must be CH_3COOH – ethanoic acid

Question 23. (4 marks)

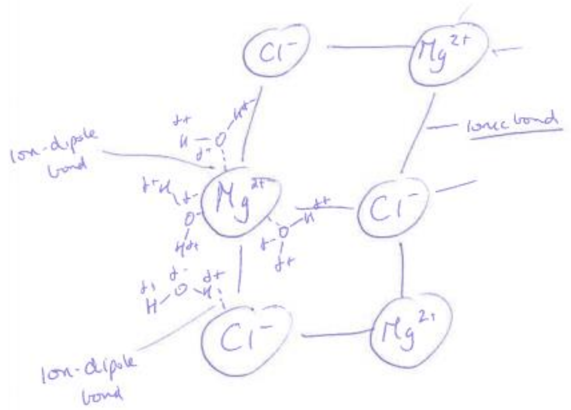
When magnesium chloride dissolves in water, changes occur in both the bonding and entropy. Explain these changes, supporting your answer with a labelled diagram.

Criteria	Marks
Explains change in bonding and entropy Includes appropriate labelled diagram	4
Explains change in bonding OR entropy Includes appropriate labelled diagram	3
Outlines change in bonding and entropy Includes a diagram	2
Provides some relevant information	1

Sample answer

When $MgCl_2$ dissolves the ionic bonds between the Mg^{2+} and the Cl^{-1} are disrupted/broken due to interference from the water molecules, which surround each ion as they form ion-dipole between the ions and the water molecule.

Since the dissolving of the solid leads to increase in the number of particles and the solid becomes aqueous (so particles more randomly arranged) so entropy is increased.



Student Number: ....

Question 24. (5 marks)

(a) Which of lead (II) sulfate and lead (II) chloride is more soluble in water at 25°C. Give a reason for your answer. **2**

Criteria	Marks
Identifies more soluble compound and gives reason	2
Identifies more soluble compound	1

Sample answer

$PbCl_2$ is more soluble as it has a larger K_{sp} than lead sulfate ($PbCl_2$ 1.70 x 10^{-5}, $PbSO_4$ 2.53 x 10^{-8})

(b) Quantitatively compare the molar solubility of lead (II) sulfate in water with its solubility in a 0.10 mol L^{-1} solution of sodium sulfate at 25°C. **3**

Criteria	Marks
• Calculates solubility in water • Calculates solubility in sodium sulfate using ICE table • Makes comparison statement	3
Two of above	2
One of above	1

Sample answer

Solubility of lead sulfate in water Ksp = 2.53 x 10^{-8}

Molar solubility – s^2 = 2.53 x 10^{-8} Therefore s = 1.59 x 10^{-4} mol/L

(Could use ice table to show this)

Solubility in 0.10 mol/L sodium sulfate

$PbSO_4$ $\rightleftharpoons$	Pb^{2+} +	SO_4^{2-}
	0	0.10
	+ s	0.10 + s
	s	0.10 (assume s not significant)

Ksp = 2.53 x 10^{-8} = s x 0.10

So s = 2.53 x 10^{-7}mol/L. This value is much small than molar solubility in water (1.59 x 10^{-4} mol/L) so lead sulfate is less soluble in sodium sulfate than in water. This is common ion effect

Question 25. (8 marks)

Sulfur trioxide is made by the reaction of sulfur dioxide and oxygen in the presence of a catalyst. In a closed system the reaction quickly reaches equilibrium.

$$2SO_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2SO_{3\,(g)} \qquad \Delta H = -196 \text{ kJ mol}^{-1}$$

A mixture of 2.00 moles of $SO_{2\,(g)}$ and 2.00 moles of $O_{2\,(g)}$ was placed in a 4.00 L vessel and kept at 1000 K until equilibrium was reached. At equilibrium the vessel was found to contain 1.66 moles of $SO_{3\,(g)}$

(a) Calculate the equilibrium constant, K_{eq}, at 1000 K **4**

Criteria	Marks
• Correctly calculates equilibrium concentrations • Applies K expression using appropriate data • Clearly shows working • Answer in 3SF	4
Most of above done correctly	3
Some of the above done correctly	2
Some relevant information	1

Sample answer

$2SO_{2\,(g)}$	$O_{2\,(g)}$ $\rightleftharpoons$	$2SO_{3\,(g)}$
0.5	0.5	0
- 0.5 – 0.415	- 0.5 – 0.2075	+ 0.415
0.085	0.2925	0.415

$K = 0.415^2 / 0.085^2 \times 0.2925 = 81.495 = 81.5$ (3Sig fig)

A manufacturer of sulfur trioxide changes the reaction conditions used in part (a) in order to increase the percentage yield in a closed system where the volume may be changed if required.

(b) What changes would the manufacturer make to the system to increase the yield of $SO_{3\,(g)}$. Justify your answer. **4**

• TWO changes identified and explained	4
• TWO changes identified and one explained	3
• ONE change identified and explained	2
• ONE change identified	1

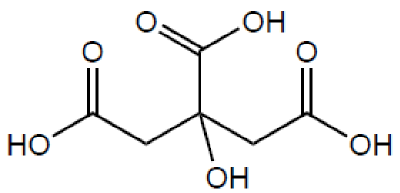
Sample answer

Change 1 – decrease temperature. As reaction is exothermic a drop in temp. will favor the forward, exothermic reaction so increasing yield. However, a compromise temp will be needed as a drop in temp also slows reaction as fewer successful collisions.

Change 2 – Increase pressure – as ratio of moles of reactant:product is 3:2, an increase in temp will favor a shift towards product side so increasing yield (this is according to Le Chatelier's Principle)

Question 26. (9 marks)

A molecule of citric acid, $C_6H_8O_7$, is shown.



The equation for the first dissociation of citric acid in water is

$$C_6H_8O_7\,(aq) + H_2O\,(l) \rightleftharpoons C_6H_7O_7^-\,(aq) + H_3O^+\,(aq)$$

a) Identify a conjugate acid–base pair in the equation. 1 mk for correct answer **1**

Acid	Conjugate base
$C_6H_8O_7$ OR H_3O^+	$C_6H_7O_7^-$ OR H_2O (respectively)

$K_a = 5.01 \times 10^{-4}$ for the first dissociation constant at 298K.

b) Explain the strength of citric acid. Include the K_a expression in your answer. **3**

Criteria	Marks
States weak acid with two appropriate reasons/points Correct expression for K	3
States weak acid with two appropriate reasons/points OR States weak acid with one appropriate reason/point Correct expression for K	2
States weak acid with one appropriate reason/point OR Correct expression for K	1

Sample answer

Citric acid is a weak acid. This is because the K value is very small. This means that the equilibrium favours the reactants/LHS. So there will be a low concentration of H_3O^+ ions – so a weak acid

$$K_a = \frac{[C_6H_7O_7^-][H_3O^+]}{[C_6H_8O_7]}$$

c) Citric acid and its conjugate base can be used as a buffer. Justify this statement. **5**

Criteria	Marks
• Defines buffer and describes features of buffer • Explains action of buffer with addition of acid and base • Supports explanation using at least two equations	5
• Defines buffer and describes features of buffer • Explains action of buffer with addition of acid OR base (or describes action of buffer with acid and base) • Supports explanation using at least one equation	4
• Defines buffer OR describes features • Explains action of buffer with addition of acid OR base (or describes action of buffer with acid and base) • Supports explanation using at least one equation	3
• Defines buffer and/or describes features • Describes action of buffer with acid or base • Supports explanation using at least one equation	2
• Provides some relevant information	1

Sample answer

A buffer is a solution of a weak acid and a salt of its conjugate base (or a weak base and a salt of the conjugate acid) that, on addition of small amounts of an acid or base will minimise any changes in pH.

$$C_6H_8O_7\ (aq) + H_2O\ (l) \rightleftharpoons C_6H_7O_7^-\ (aq) + H_3O^+\ (aq)$$

If an acid was added to this system, the addition of the extra H_3O^+ will, according to LCP, shift the =bm to the left, so removing H_3O^+ so minimizing any changes to the concentration of H_3O^+ so keeping pH relatively constant.

If a base is added the following reaction takes place - $H_3O^+ + OH^- \rightleftharpoons H_2O$

So adding hydroxide ions removes hydronium ions, thus the =bm will move to the right, producing more hydronium ions and so maintain the pH

Question 27. (4 marks)

A student determined the concentration of an unknown solution of sulfuric acid using the following method:

Step 1: She weighed out 4.00 grams of sodium carbonate.

Step 2: She dissolved the sodium carbonate in a little distilled water and made it up to 1000 mL in a volumetric flask. This became her 0.10 mol L^{-1} standard solution.

Step 3: She then carried out a titration using 25.0 ml of the 0.10 mol L^{-1} sodium carbonate with the unknown sulfuric acid.

Bromothymol blue was the indicator.

Her results were recorded in the table below.

Titration	Volume of sulfuric acid used mL)
1	5.6
2	5.2
3	4.8

Assess the validity and reliability of this method and results. **4**

Criteria	Marks
• Makes assessments on both validity and reliability • Addresses both method and results in answer	4
• Makes assessments on both validity and reliability • Addresses method or results in validity and reliability	3
• Makes assessments on validity or reliability • Addresses both method and results	2
• Some relevant information	1

Sample answer

Method

Validity – not valid as 4g would give a 0.037 mol/L solution,

Reliability – only done once so not reliable

Results – Validity – not valid as the indicator not correct (strong acid, weak base – phenolphthalein better choice) Reliability – one set of results which vary a lot and so unreliable

Question 28. (7 marks)

A conductivity graph can be used to determine sodium ion concentration in water samples.

A sample of water was collected from a bore (*i.e.* by drilling into an underground water reservoir). 10 mL of the sample was diluted with deionised water to a final volume of 1000 mL in a volumetric flask.

Six standard solutions containing a known concentration of sodium ions were also prepared.

Conductivities of the sample and standard solutions were determined. The results are shown in the table.

Na^+ concentration (ppm)	Conductivity
0	0
2	0.26
4	0.48
6	0.71
8	0.95
10	1.2

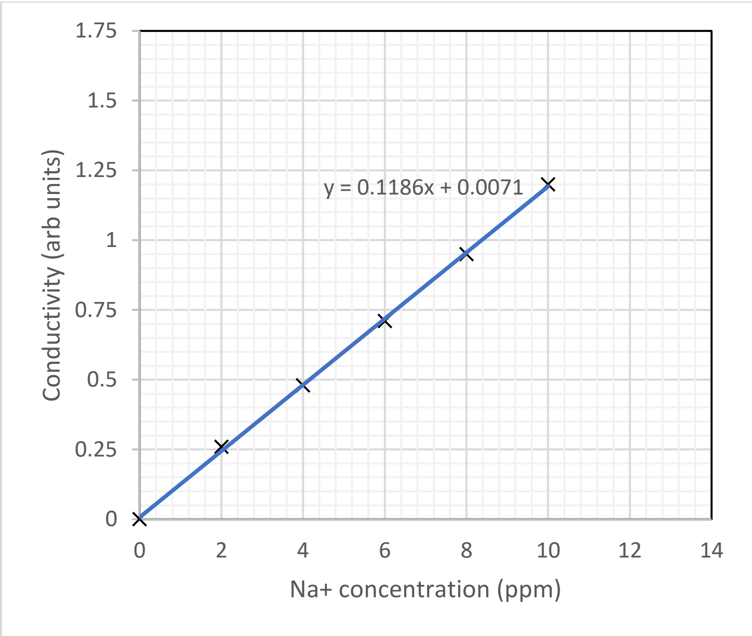
The bore sample had a conductivity of 0.78.

Based on taste, the following guidelines have been suggested for assessing the quality of drinking water.

- less than 2.6×10^{-2} mol/L of sodium is regarded as good quality drinking water.
- 2.6×10^{-2} to 3.9×10^{-2} mol/L of sodium is regarded as fair quality.
- 3.9×10^{-2} to 5.2×10^{-2} mol/L of sodium is regarded as poor quality.
- greater than 5.2×10^{-2} mol/L of sodium is regarded as unacceptable.

Criteria	Marks
• Graph correct – axes accurate/labelled, points, line (3 max) • Uses graph to get ppm from conductivity (1) • Calculates conc. in moles/L from ppm (2) • Makes statement on water quality (1)	7
• Errors from each dot point – lose 1 mk • Graph correct – axes accurate/labelled, points, line (3 max) • Uses graph to get ppm from conductivity (1) • Calculates conc. in moles/L from ppm (2) • Makes statement on water quality (1)	1-6

Sample answer



Na^+ conc^n = 6.4 ppm

Dilution was 100 x so actual $[Na^+]$ in original sample = 6.4 x 100 = 640 ppm

640 ppm = 640 mg/L

= 0.640 g/L

$n[Na^+] = \frac{0.640}{22.99} = 2.78 \times 10^{-2}$

∴ conc^n of Na^+ = 2.78×10^{-2} mol L^{-1}

= Fair quality.

C	ppm	actual [Na+]	g/L	moles Na
0.78	**6.5169**	**651.6863**	**0.6517**	**2.83E-02**
	6.0000	600.0000	0.6000	2.61E-02
	6.1000	610.0000	0.6100	2.65E-02
	6.2000	620.0000	0.6200	2.70E-02
	6.3000	630.0000	0.6300	2.74E-02
	6.4000	640.0000	0.6400	2.78E-02
	6.5000	650.0000	0.6500	2.83E-02
	6.6000	660.0000	0.6600	2.87E-02
	6.7000	670.0000	0.6700	2.91E-02
	6.8000	680.0000	0.6800	2.96E-02
	6.9000	690.0000	0.6900	3.00E-02
	7.0000	700.0000	0.7000	3.04E-02

Question 29. (6 marks)

A sample of white powder contained mostly magnesium oxide mixed with an unknown amount of an impurity. The impurity does not react with acid.

To determine the percentage purity of magnesium oxide in the white powder, 2.65 g of the powder was weighed out and reacted in 50 mL of 2.0 mol L^{-1} hydrochloric acid. The reaction mixture was then diluted with water to 250 mL in a volumetric flask.

Four samples of 25mL of the diluted reaction mixture were titrated against a standardised 0.10 mol L^{-1} solution of sodium hydroxide using a phenolphthalein indicator. The titre of sodium hydroxide used in the titrations is shown in the table.

Titration	Volume NaOH (mL)
1	17.2
2	15.5
3	15.4

Calculate the percent by mass of magnesium oxide in the white powder.

Criteria	Marks
• Correct equation • Calculates initial nHCl, n NaOH, unreacted nHCl, n MgO, m MgO and %	6
• 6 of above	5
• 5 of above	4
• 4 of above	3
• 2-3 of above	2
• 1 of above	1

Sample answer

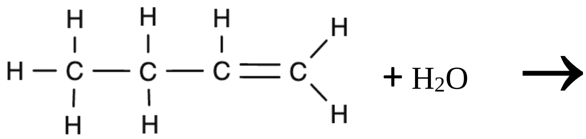
- $2HCl_{(aq)} + MgO_{(s)} \rightarrow MgCl_{2\,(aq)} + H_2O_{(l)}$
- Tablet dissolved in HCl: initial n HCl = 0.050 x 2 = 0.100 moles

Second reaction HCl + NaOH: mole ratio = 1:1
Avg vol of NaOH = (15.5 + 15.4) /2= 15.45 mL
n NaOH = .01545 x 0.1 = 0.001545 moles. This reacts with same n moles of HCl
therefore, unreacted n HCl in 25mL sample = 0.001545 moles.
in 250 mL = 10 x 0.001545 = 0.01545 moles
Of the original HCl, 0.1 – 0.01545 = 0.08455 moles reacted with MgO
Since mole ratio = 2:1, the tablet contained n MgO = 0.5 x 0.08455 = 0.042275 moles
mass MgO = n x MM = 0.042275 x 40.31 = 1.7045 = 1.70g
% = 1.70/2.65 x 100/1 = 64.15% or 64% (2SF)

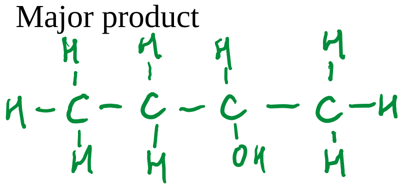
Question 30. (3 marks)

Water can be added to but-1-ene to form two products.

Complete the boxes to show the structural formulae for the products and identify a relevant catalyst. **3**



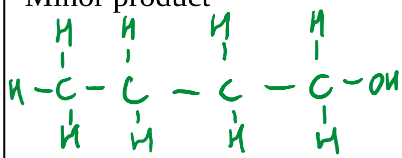
Major product



Catalyst

DILUTE ACID | H^+ | H_2SO_4

Minor product



Criteria	Marks
• 3 boxes correctly completed	3
• 2 boxes correctly completed	2
• 1 boxes correctly completed	1

Student Number: ....

Question 31. (7 marks)

The table shows the solubility of alcohols in water at 25°C

Formula	Name	Solubility in Water (g/100ml)
CH_3OH	1-methanol	Greater than 10
CH_3CH_2OH	1-ethanol	Greater than 10
$CH_3(CH_2)_2OH$	1-propanol	Greater than 10
$CH_3(CH_2)_3OH$	1-butanol	7.3
$CH_3(CH_2)_4OH$	1-pentanol	2.2
$CH_3(CH_2)_5OH$	1-hexanol	0.59
$CH_3(CH_2)_6OH$	1-heptanol	0.17
$CH_3(CH_2)_7OH$	1-octanol	0.03

a) Describe one procedure to ensure safe handling of these substances. **2**

Criteria	Marks
• Appropriate procedure named and reason given	2
• Appropriate procedure named	1

Sample answer
The alcohols should be handled in a fume cupboard as this removes the toxic volatile vapours produced by alcohols at room temperature.
Other answers could include avoiding naked flames, reducing skin contact, not ingesting!!

b) Explain the trend in solubility in terms of intermolecular forces. **3**

Criteria	Marks
• Trend described • Appropriate reference to intermolecular forces • Relate intermolecular forces to trend	3
• Trend described • Appropriate reference to intermolecular forces	2
• Some relevant information	1

Sample answer
As the length of the hydrocarbon chain in the alcohol increases, so the solubility of the alcohol in water decreases.
Alcohols are soluble in water due to the hydrogen bonding between the water molecules and the hydroxyl group. (Water is a polar molecule and the hydroxyl group is also polar – like

dissolves like). As the non-polar HC chain increases in length, it is more likely to interfere with (or disrupt) the hydrogen bonding so reducing the solubility.

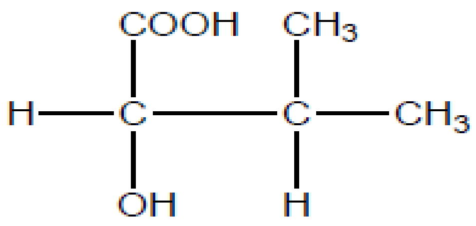
c) 1-bromobutane will react with sodium hydroxide. Name the products of this reaction. **2**

Criteria	Marks
• 2 products named	2
• 1 product named	1

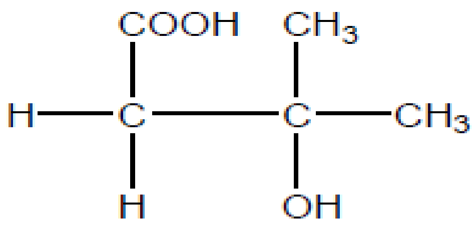
Sample answer – butan-1-ol + sodium bromide

Question 32. (4 marks)

The structural formulas of two organic compounds are shown below.



A



B

A chemist needed to distinguish between these compounds.

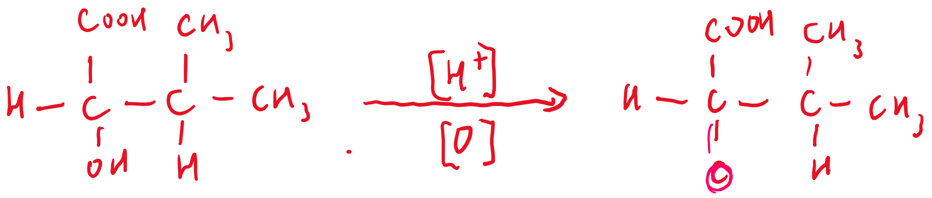
Justify a test that could be used to distinguish the compounds and the result of that test. Include an equation in your answer.

Criteria	Marks
• State difference between the alcohols • Describe a test and results of this test • Explains result in terms of oxidation • Equation included	4
• State difference between the alcohols • Describes a test • Explains result	3
• Two of above	2
• Some relevant information	1

Sample answer

Compound A is a secondary alcohol and compound B is a tertiary alcohol.

To distinguish between these add some acidified dichromate (yellow) or permanganate (purple). Compound A will turn the solution green (or colourless) while compound B will not show any colour change. This is because secondary alcohols undergo oxidation to form ketones, while tertiary alcohols do not undergo oxidation.



Student Number: …………………………………

Question 33. (5 marks)

An ester can be produced from two organic compounds and a catalyst.

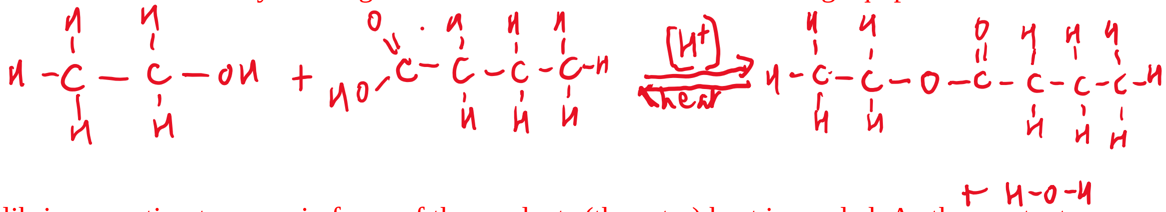
Justify a procedure for the production of ethyl butanoate in a school laboratory. In your answer include the following:

- the structural formulae equation of this reaction;
- an explanation of the conditions and equipment needed to efficiently and safely carry out this reaction in the school laboratory; and
- a risk assessment.

Criteria	Marks
• structural formula included • explanation of conditions AND equipment used • justification statement • one appropriate risk assessment	5
• structural formula included • explanation of conditions AND equipment used • one appropriate risk assessment	4
• structural formula included • explanation of conditions OR equipment used • one appropriate risk assessment	3
• Two of above	2
• Some relevant information	1

Sample answer

Ethyl butanoate is an ester made by reacting ethanol with butanoic acid in refluxing equipment.



For this equilibrium reaction to occur in favor of the products (the ester) heat is needed. As the reactants produce volatile vapors, a heating mantle is used (not a naked flame). The heat increases collisions between reactants. The refluxing equipment consists of a condenser, which is unstoppered (otherwise vapor pressure could increase causinq reactant vessel to break). As the reaction vessel is heated the vapors are produced but in the condenser they are cooled back to liquid form and return to the reaction vessel, so preventing loss of both reactants and products, so increasing yield of ester. The presence of a conc. Sulfuric acid catalyst increase yield of ester as the acid removes water so shifting equilibrium to right

Risk assessment – avoid naked flames as the volatile vapous from alcohol could ignite causing burns. Reduce risk by using heating mantle and water bath

NOTE – a well annotated diagram is also OK

Structural diagram – must include Water on RHS. Arrow must be reversible.

Student Number: ……………………………….….

Question 34. (6 marks)

Ethene is a very important molecule extracted from fossil hydrocarbon sources. It is used as a starting molecule to produce polyvinylchloride (PVC). Initially it is converted to vinyl chloride, according to the following equation.

$$Cl_{2(g)} + C_2H_{4\,(g)} \rightarrow C_2H_3Cl_{(g)} + HCl$$

a) What is the IUPAC systematic name for vinyl chloride? **1**

Correct name given = 1 mark

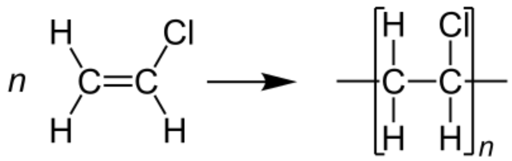
Chloroethene

b) How could you test that all the ethene had been converted to vinyl chloride? **2**

Criteria	Marks
• Describes test and results	2
• Identifies a test	1

Sample answer – if ethene is present than the addition of bromine water will show this. The brown bromine water will quickly become colourless in the presence of ethene

Vinyl chloride is then used to produce PVC



Assume n = 1200.

c) What volume of ethene measured at 25°C and 100kPa would be required to make 1.00 kilogram of PVC if the average molecular mass for PVC is 75.00 kg/mol? **3**

Criteria	Marks
• Calculate moles of PVC • Calculate moles of monomer • Calculate volume of monomer	3
• 2 of above	2
• 1 of above	1

Sample answer

nPVC = 1/75.00 = 0.013333 mol

nC_2H_3Cl = 1200 x 0.01333 = 16 mol

vol = n x MV = 16 x 24.79 = 396.64L (397L 3SF)

Question 35. (7 marks)

An experiment was conducted to find the heat of neutralisation in an acid-base reaction.

A solution was made by dissolving 3.79g of barium hydroxide in 100 mL of water. 30.0 mL of this barium hydroxide solution was reacted with 27.0 mL of a 0.400 mol L^{-1} solution of nitric acid. The heat of neutralisation was calculated to be 51.7 kJ mol^{-1} .

Calculate the temperature change and the resultant pH of the solution.

Criteria	Marks
• Correct equation • Calculates $nHNO_3$ • Calculates n(OH) • Identifies limiting reagent • Calculates q and then ΔT • Finds excess[OH] • Calculates pH • Correct significant figures	7
• Some of above	1-6

$Ba(OH)_2 + 2HNO_3 \longrightarrow Ba(NO_3)_2 + 2H_2O$

3.79g in 100mL   27mL

0.400

$n\ HNO_3 = 0.027 \times 0.4 = 0.0108$ mol

$n\ Ba(OH)_2 = \frac{3.79}{171.176} = 0.0221228$ mol

$c\ Ba(OH)_2 = \frac{n}{V} = \frac{0.0221228}{0.1} = 0.221 4613$ mol L^{-1}

so in 30mL sample will have 0.0066438 mol of $Ba(OH)_2$

so $n(OH^-)$ will be twice this $= 0.0132877$

$n\ H^+ = 0.0108$ $n\ OH^-\ 0.0132877$

∴ acid is limiting reagent

$\Delta H = \frac{q}{n}$ ∴ $q = n \times \Delta H = 0.0108 \times 51.7 = 558.36$ J

∴ $558.36 = 57 \times 4.18 \times \Delta T$

$\Delta T = 2.34°C$

pH excess $OH^- = 0.0132877 - 0.0108 = 0.0024877$ in 57mL

$c[OH^-] = \frac{n}{V} = 0.043644$

$pOH = -\log[OH^-] = 1.36.$

∴ $pH = 14 - 1.36 = 12.64$

3 sig fig answer

pH= 12.637

END OF EXAMINATION

Student Number: ....

2019 | HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

FORMULAE SHEET

$n = \frac{m}{MM}$ $\quad c = \frac{n}{V}$ $\quad PV = nRT$

$q = mc\Delta T$ $\quad \Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $\quad \text{pH} = -\log_{10}[\text{H}^+]$

$pK_a = -\log_{10}[K_a]$ $\quad A = \varepsilon lc = \log_{10}\frac{I_o}{I}$

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}

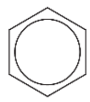
Compound	K_{sp}
Lead(II) bromide	6.60×10^{-6}
Lead(II) chloride	1.70×10^{-5}
Lead(II) iodide	9.8×10^{-9}
Lead(II) carbonate	7.40×10^{-14}
Lead(II) hydroxide	1.43×10^{-15}
Lead(II) phosphate	8.0×10^{-43}
Lead(II) sulfate	2.53×10^{-8}
Magnesium carbonate	6.82×10^{-6}
Magnesium hydroxide	5.61×10^{-12}
Magnesium 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

Student 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.

Student Number: ………………………………….

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