South Australian
Certificate of Education

1

Chemistry
2019

Question booklet 1

- Questions 1 to 4 (60 marks)
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on page 14 if you need more space
- Allow approximately 65 minutes

Examination information

Materials
- Question booklet 1
- Question booklet 2
- Periodic table and data sheet
- SACE registration number label

Instructions
- Use black or blue pen
- You may use a sharp dark pencil for diagrams and other representations
- Approved calculators may be used

Total time: 130 minutes
Total marks: 120

Attach your SACE registration number label here

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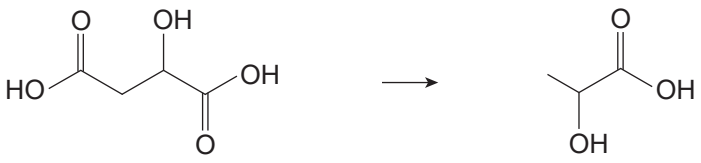
1. Winemakers may use some of their wine to produce sparkling wine. The production of sparkling wine involves two main chemical reactions.

(a) The first reaction converts malic acid to lactic acid, as shown below.



malic acid **lactic acid**

(i) Malic acid contributes more to the acidity of wine than lactic acid does.

With reference to the structural formulae above, explain why this is so.

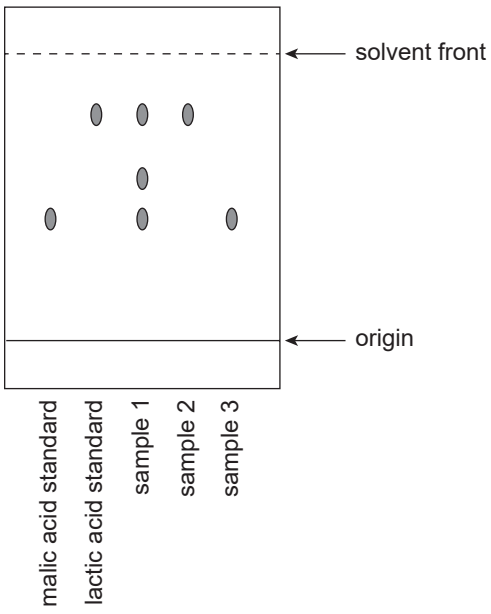
_____

_____

_____

_____ (2 marks)

(ii) Thin-layer chromatography was used to test whether or not the conversion of malic acid to lactic acid went to completion in samples of three different wines. The result of this test is shown in the chromatogram below.



Using the information in the chromatogram on page 2, explain whether or not the conversion went to completion in the three samples.

Sample 1: _____

_____

Sample 2: _____

_____

Sample 3: _____

_____ (3 marks)

(b) The second reaction is fermentation, which occurs inside the wine bottle. Yeast and glucose are added to the wine and then the bottle is sealed to allow fermentation to occur.

(i) Write an equation for the fermentation of glucose.

(2 marks)

(ii) A narrow range of wine temperatures is used for the fermentation process.

Explain why winemakers should not allow the wine temperature to rise above this range.

_____

_____

_____

_____

_____

_____ (3 marks)

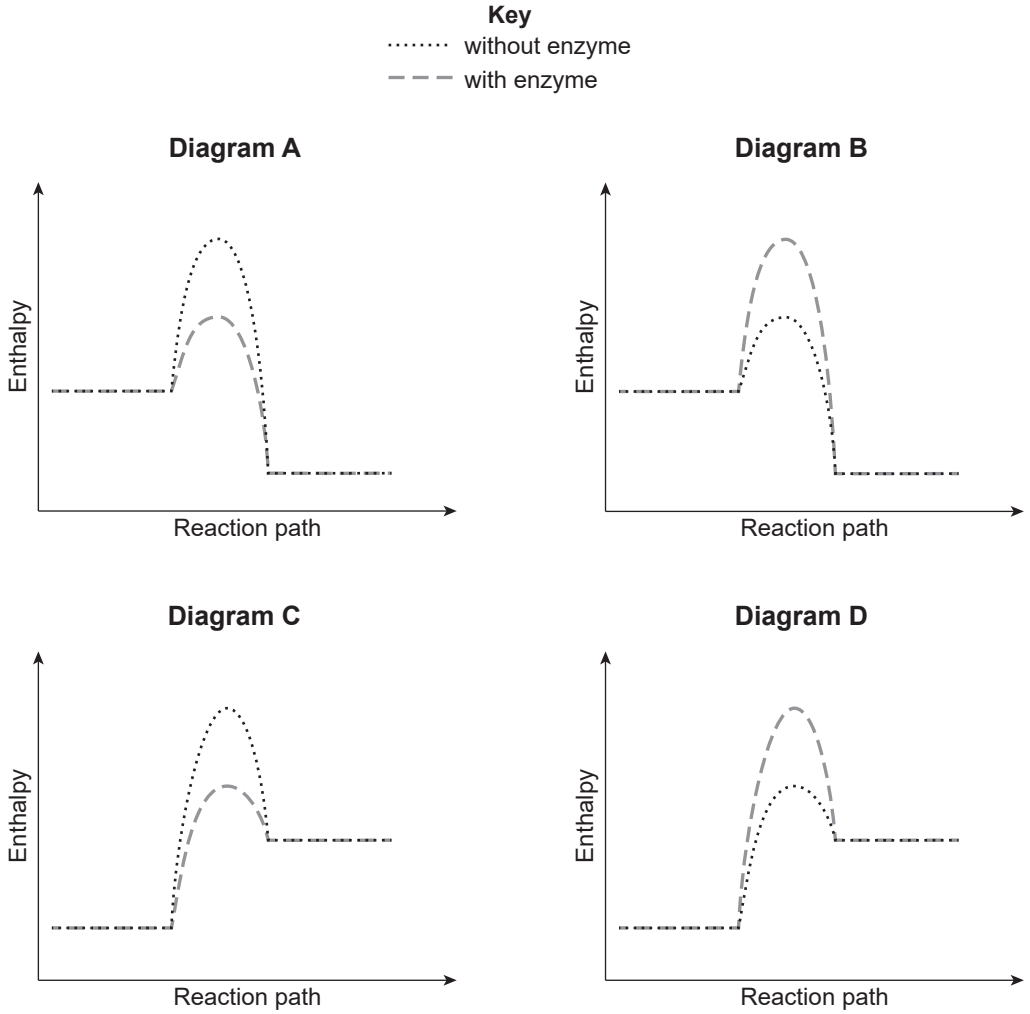
(iii) The CO_2 produced during fermentation reacts with water to form carbonic acid in the wine.

(1) Write an equation for this reaction.

(2 marks)

(2) When a person drinks the wine, an enzyme in their mouth catalyses an endothermic reaction that converts carbonic acid into CO_2 and water.

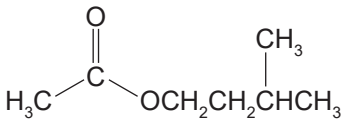
Refer to the four energy profile diagrams below.



Identify which *one* of the four diagrams — A, B, C, or D — is a correct representation of the energy profile for the reaction that converts carbonic acid into CO_2 and water.

Diagram: _____ (2 marks)

(c) The structural formula of one ester found in sparkling wine is shown below.

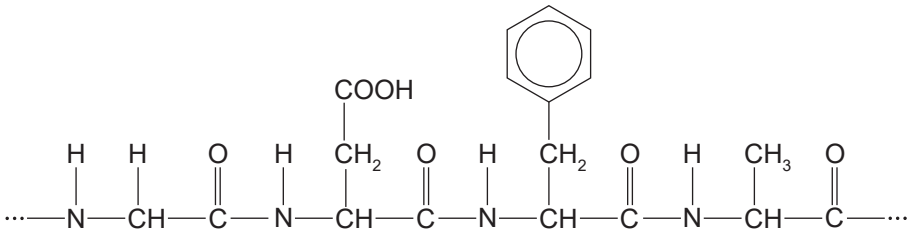


Name the alcohol that reacts to produce this ester.

_____ (2 marks)

2. Wine contains proteins from grapes.

(a) A section of one of these proteins, protein A, is shown below.



(i) Draw the structural formula of *one* of the amino acids that was used to synthesise protein A.

(2 marks)

(ii) Proteins in wine can be positively charged, negatively charged, or uncharged, depending on the pH of the wine.

(1) Protein A is uncharged in a wine that has a pH of 3.2.

Determine the hydrogen ion concentration, in mol L^{-1}, in this wine.

(2 marks)

(2) State and explain the effect that increasing the pH of the wine has on the overall charge on protein A.

_____

_____

_____

_____

_____

_____ (3 marks)

(b) Several different substances can be used to remove unwanted proteins from wine, in order to improve characteristics of the wine. The table below compares the effectiveness of five different substances in improving the characteristics of colour, taste, and clarity.

decreasing effectiveness ↓

Colour	*Taste*	*Clarity*
carbon	gelatine	bentonite
gelatine	egg white	carbon
casein	casein	casein
egg white	bentonite	gelatine
bentonite	carbon	egg white

Source: adapted from Zoecklein, B 1990, *Protein fining agents for juices and wines*, Virginia Polytechnic Institute & State University, Virginia, table 3

(i) Using the information in the table above, state the reason why a winemaker would decide to use bentonite rather than casein to remove unwanted proteins from their wine.

_____ (1 mark)

(ii) Bentonite is a very fine clay made of aluminosilicate. Its formula is shown below.

$$Na_2Al_2Si_4O_{12}\cdot H_2O$$

State the charge on the aluminosilicate anion in bentonite.

_____ (1 mark)

(iii) Bentonite removes positively charged proteins from wine.

One wine is treated with a mixture of bentonite and water. The mixture is added to the wine, which is then stirred and left to stand until flocculation occurs and a sediment forms.

(1) Proteins with a greater overall positive charge are removed more readily by the bentonite mixture than proteins with a lesser overall positive charge.

Explain why this is so.

_____

_____

_____

_____ (2 marks)

(2) Name *one* process that could be used to remove this resulting sediment from wine.

_____ (1 mark)

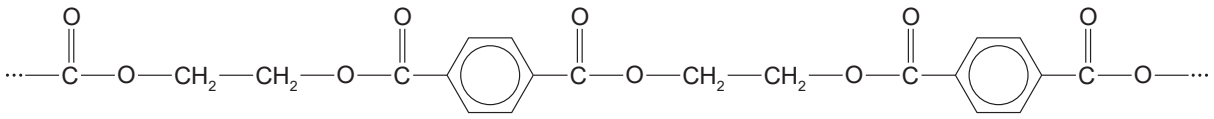
(3) A bentonite mixture of 5 g per 100 mL of water is prepared. 15 mL of this bentonite mixture is required in order to treat 100 mL of wine.

Calculate the mass, in kg, of bentonite that is required in order to treat 700 L of wine.

(4 marks)

3. There is increasing global concern about the number of plastic items that are used only once before being thrown away.

(a) Many single-use plastic takeaway food containers are made of polyethylene terephthalate, PET. The structural formula of a section of the PET polymer chain is shown below.



(i) *On the structural formula above*, draw brackets around *one* repeating unit. (1 mark)

(ii) State the type of polymerisation reaction that is used to synthesise PET.

_____ (1 mark)

(iii) Two monomers were used to synthesise PET.

Describe the essential features of these two monomers that enable this polymerisation reaction to occur.

_____

_____

_____

_____ (2 marks)

(b) Plastic is commonly used as a waterproof covering for food. One substitute for plastic is cloth that has been coated with beeswax. The condensed structural formula for the most abundant molecule in beeswax is shown below.

$$C_{15}H_{31}COOC_{30}H_{61}$$

By referring to this structural formula, explain why cloth coated with beeswax is waterproof.

_____

_____

_____

_____

_____

_____ (3 marks)

(c) In January 2019 it was announced that the South Australian Government is considering banning the supply of some single-use plastic items such as straws, takeaway coffee cups, and plastic bags.

Using relevant chemical concepts, justify the proposed ban.

(6 marks)

4. Triglycerides are found in food, and are also feedstock for the manufacture of industrial liquids.

(a) One triglyceride in olive oil is produced in a reaction between glycerol and linoleic acid. The formula for linoleic acid is shown below.

$$CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7COOH$$

(i) Draw the structural formula of this triglyceride.

(2 marks)

(ii) A sample of this triglyceride was placed in a test tube and shaken with a few drops of orange-coloured bromine solution.

Describe and explain the observation during this reaction.

_____

_____

_____

_____ (2 marks)

(b)

In 1968, scientists in the USA were trying to make synthetic fat molecules that could be easily digested by premature babies. They discovered a new molecule, olestra, which is similar in structure to a triglyceride. Olestra is produced by chemically combining sugar and vegetable oil. Olestra has a similar taste and texture to fat, but it passes through the body undigested and so contributes no kilojoules to the body.

Olestra was approved for use as a food additive in snack foods in 1996, and was advertised as a healthy alternative to dietary fat because it does not add kilojoules to food. Unfortunately, many people who consumed foods containing olestra suffered from gastrointestinal side effects, including intense diarrhoea, and sales of foods containing olestra declined after a few years.

Further research into the uses for olestra has now led to its use as a non-toxic replacement for petrochemicals that are used as feedstock for the manufacture of industrial lubricants and paint additives.

One of the key concepts of science as a human endeavour is 'application and limitation'.

Discuss examples in the text above that illustrate this key concept.

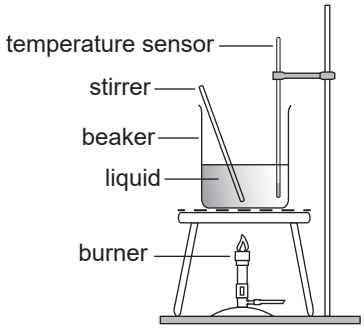
(4 marks)

Question 4 continues on page 12.

(c) The specific heat capacity, *c*, of a liquid is the amount of heat, in joules, required in order to raise the temperature of 1 g of the liquid by 1°C. The value of *c* varies for different liquids.

An investigation was performed to compare the specific heat capacity of canola oil with the specific heat capacity of water. The following procedure was followed, first using water and then repeated using canola oil:

Step 1. A sample of the liquid was added to a beaker and placed above a burner. A temperature sensor was placed in the beaker, as shown in the diagram below.



Step 2. The liquid was stirred and heated until its temperature reached 35°C.

Step 3. The liquid was heated for a further 60 s, and data from the temperature sensor during this 60 s were plotted on a graph.

(i) Identify the independent variable in this investigation.

_____ (1 mark)

(ii) Identify *one* variable that must be held constant in this investigation, and explain why it must be held constant.

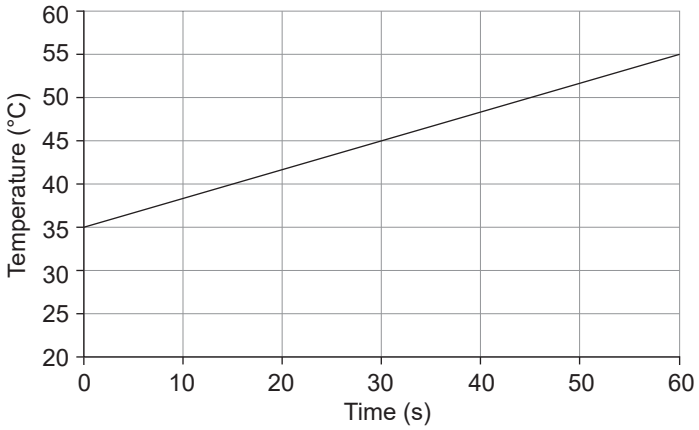
_____

_____

_____

_____ (2 marks)

(iii) The data from the temperature sensor in the beaker of canola oil were used to construct the graph below.



The mass of canola oil in the beaker was 20 g. From 0 s to 60 s, the heat energy released from the burner was 1300 J.

(1) Using data from the graph, calculate the experimental value of *c*, in J g^{-1} °C^{-1}, for this sample of canola oil.

(2 marks)

(2) The actual value of *c* for this sample of canola oil is 2.2 J g^{-1} °C^{-1}.

Suggest why the experimental value that you calculated in part (c)(iii)(1) is higher than the actual value.

(2 marks)

PLEASE TURN OVER

You may write on this page if you need more space to finish your answers to any of the questions in this question booklet. Make sure to label each answer carefully (e.g. 4(c)(iii)(2) continued).

South Australian
Certificate of Education

Chemistry
2019

Question booklet 2

- Questions 5 to 8 (60 marks)
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on page 12 if you need more space
- Allow approximately 65 minutes

2

Copy the information from your SACE label here

SEQ	FIGURES	CHECK LETTER	BIN

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5. Soil productivity is related to the availability of plant nutrients. Fertilisers can increase the concentration of plant nutrients such as calcium, magnesium, potassium, and nitrogen in soil.

(a) Soil silicates adsorb cations such as Ca^{2+} and Mg^{2+} onto their surfaces.

(i) Using subshell notation, write the electron configuration of Ca^{2+}.

_____ (2 marks)

(ii) Ca^{2+} and Mg^{2+} were extracted from a sample of soil silicates.

(1) The concentration of Ca^{2+} in the extract was determined by AAS, using a calcium lamp as the light source.

Describe how the necessary data for constructing the AAS calibration graph would have been obtained.

_____

_____

_____

_____

_____

_____ (3 marks)

(2) Explain why it would be necessary to use a magnesium lamp as the AAS light source when determining the concentration of Mg^{2+} in the extract.

_____

_____

_____

_____ (2 marks)

(b) An equilibrium exists between potassium ions adsorbed onto the surfaces of soil silicates and potassium ions dissolved in soil water, as shown in the equation below.

$$K^+_{(silicate)} \rightleftharpoons K^+_{(aq)}$$

A fertiliser containing $K^+_{(aq)}$ is added to a nutrient-deficient soil.

Using the equation above, explain the effect that adding this fertiliser will have on the number of potassium ions adsorbed onto the surfaces of soil silicates.

(3 marks)

(c) Plants absorb nitrogen from the soil.

(i) State *one* type of molecule that is made in a plant and contains nitrogen.

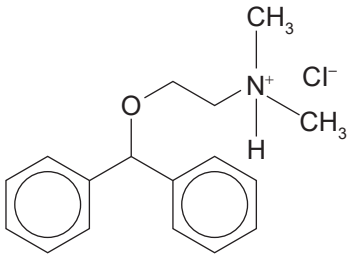
(1 mark)

(ii) Explain why nitrogen-based fertilisers that have been added to soil can often be found in nearby water bodies.

(2 marks)

6. Antihistamines are organic compounds that can be used in medications.

(a) Diphenhydramine, DPH, is an antihistamine that is used to relieve a dry cough. It is present in some cough syrups in the form of its salt (diphenhydramine hydrochloride, $C_{17}H_{22}NOCl$), because the salt is more soluble than DPH in the cough syrup. The structural formula of diphenhydramine hydrochloride is shown below.



(i) Draw the structural formula of DPH.

(2 marks)

(ii) Suggest why the salt is more soluble in the cough syrup than DPH is.

_____

_____

_____

_____

_____

_____ (3 marks)

(iii) The concentration of diphenhydramine hydrochloride in one cough syrup for children is 8.6 mmol L^{-1}. (Molar mass of $C_{17}H_{22}NOCl = 291.8$ g mol^{-1}.)

Convert this concentration to g L^{-1}.

(2 marks)

(iv) One cough syrup for adults was analysed to find its concentration of diphenhydramine hydrochloride, using the following procedure:

Step 1 — conversion

The diphenhydramine hydrochloride in a 5.00 mL sample of the cough syrup was converted to DPH.

Step 2 — dilution

This sample was then diluted, using a suitable solvent, to 100.0 mL in a volumetric flask.

Step 3 — titration

A 20.00 mL aliquot of this diluted solution was titrated with a perchloric acid solution of concentration 2.00×10^{-3} mol L^{-1}. The titre value was 22.94 mL.

(1) DPH and perchloric acid react in a mole ratio of 1:1.

Calculate the concentration, in mol L^{-1}, of DPH in the diluted solution. Give your answer correct to the appropriate number of significant figures.

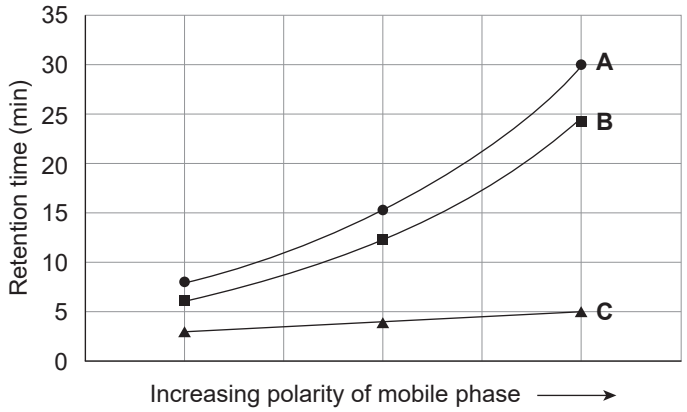
(4 marks)

(2) Hence determine the concentration, in mol L^{-1}, of diphenhydramine hydrochloride in the cough syrup for adults.

(2 marks)

(b) Three different brands of cough syrup, **A**, **B**, and **C**, each contain a different antihistamine. High-performance liquid chromatography (HPLC) was used to identify the antihistamine in each cough syrup. Each cough syrup was analysed three times, using a non-polar stationary phase and three mobile phases of increasing polarity.

Refer to the graph below, which shows retention times for the antihistamines in cough syrups **A**, **B**, and **C** in each of the three analyses.



(i) State and explain the polarity of the antihistamine in cough syrup **C** relative to the polarities of the antihistamines in cough syrups **A** and **B**.

(3 marks)

(ii) A mixture containing the three antihistamines from cough syrups **A**, **B**, and **C** was prepared.

Using evidence from the graph, explain whether a higher or lower polarity of the mobile phase would enable the *best* separation of the three antihistamines from this mixture.

(2 marks)

7. Combustion engines in motor vehicles produce a large percentage of the nitrogen oxides in Australia's atmosphere.

(a) Inside a combustion engine, a reaction occurs between nitrogen and oxygen to form nitric oxide, as shown in the equation below.

$$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)} \qquad \Delta H = +90.1 \text{ kJ mol}^{-1}$$

(i) State why the high pressure inside a combustion engine does ***not*** affect the position of the equilibrium for this reaction.

_____

_____ (1 mark)

(ii) Explain the effect that the high temperature inside a combustion engine has on the position of the equilibrium for this reaction.

_____

_____

_____

_____

_____

_____ (3 marks)

(iii) Using the equation above, calculate the heat energy that is absorbed when 3.00 kg of nitrogen gas is converted to nitric oxide.

(3 marks)

(iv) State why this reaction requires more than 90.1 kJ mol^{-1} of heat energy in order to proceed.

_____

_____ (1 mark)

(b) Nitric oxide reacts with oxygen to produce nitrogen dioxide, NO_2. The equation for this reaction is shown below.

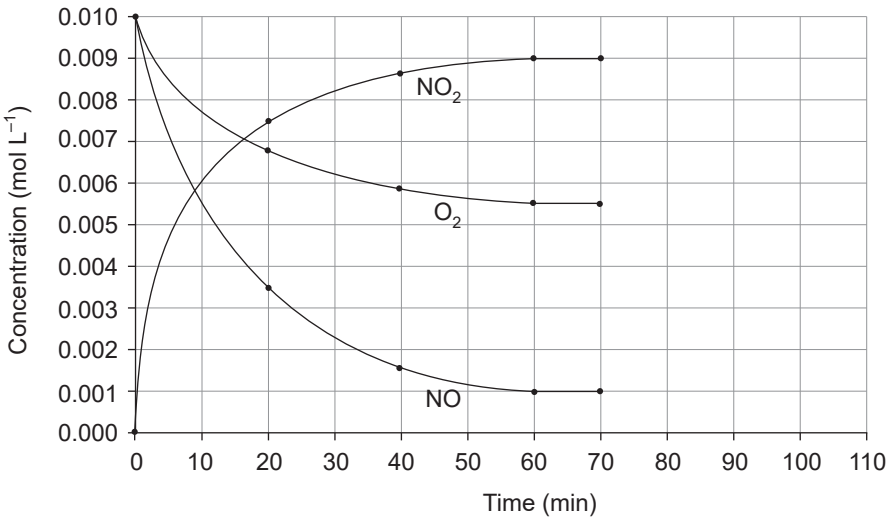
$$2NO_{(g)} + O_{2(g)} \rightleftharpoons 2NO_{2(g)}$$

(i) Write the expression for the equilibrium constant, K_c, for this reaction.

$K_c =$

(2 marks)

(ii) Nitric oxide and oxygen gases were added to an empty vessel, which was then sealed. The system was left at a constant temperature to reach equilibrium. The changes in concentrations of the three gases over time are shown in the graph below.



(1) (A) State the length of time that the system took to reach equilibrium.

_____ (1 mark)

(B) Using the concentrations of the gases at equilibrium, calculate the K_c for the reaction at this temperature.

(2 marks)

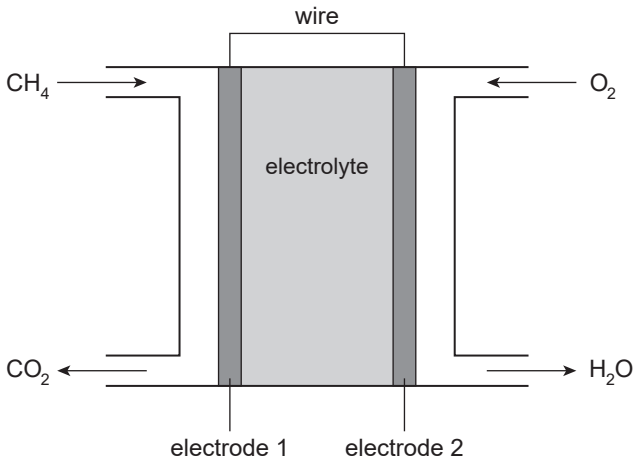
(2) At 70 minutes, there was a sudden, small decrease in pressure inside the vessel.

At 100 minutes, equilibrium was re-established.

On the graph above, draw the continuation of the line for NO_2 from 70 to 110 minutes. (3 marks)

8. The use of fuel cells as energy sources is widespread throughout the world.

(a) Consider the fuel cell shown in the diagram below, which uses methane from natural gas to generate electricity.



(i) Complete the half-equation below for the reaction that occurs at electrode 1.

$$CH_4 \longrightarrow CO_2$$

(2 marks)

(ii) Using your half-equation, explain whether electrode 1 is the anode or the cathode.

_____

_____

_____ (2 marks)

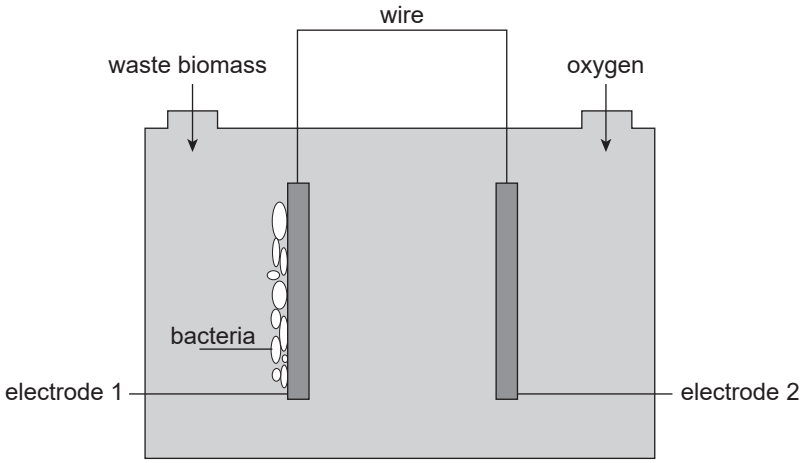
(iii) Explain *one* advantage of producing energy from fuel cells rather than from other galvanic cells.

_____

_____ (2 marks)

Question 8 continues on page 10.

(b) One development in fuel-cell technology is the microbial fuel cell (MFC), shown in the diagram below. Microbes on the surface of electrode 1 are fed waste biomass, such as sewage. The microbes oxidise organic compounds in the biomass, forming carbon dioxide.



(i) Describe *one* advantage of generating electricity from an MFC, rather than from a fuel cell that uses methane from natural gas.

_____

_____

_____

_____ (2 marks)

(ii)

Researchers are developing alternative types of MFCs. In a plant MFC, the waste biomass near electrode 1 is replaced by plant roots. The plants excrete sugars through their roots. Bacteria around the roots break down these sugars, thus producing energy.

The energy produced by a plant MFC is not sufficient to power large-scale applications; however, researchers claim that more energy is produced by a plant MFC than by the combustion of biogases.

Researchers also claim that plant MFCs are more economically viable than solar panels for energy production in remote areas.

Consider the key concepts of science as a human endeavour.

Using *one* of these key concepts, describe how plant MFC technology is an example of science as a human endeavour.

_____

_____

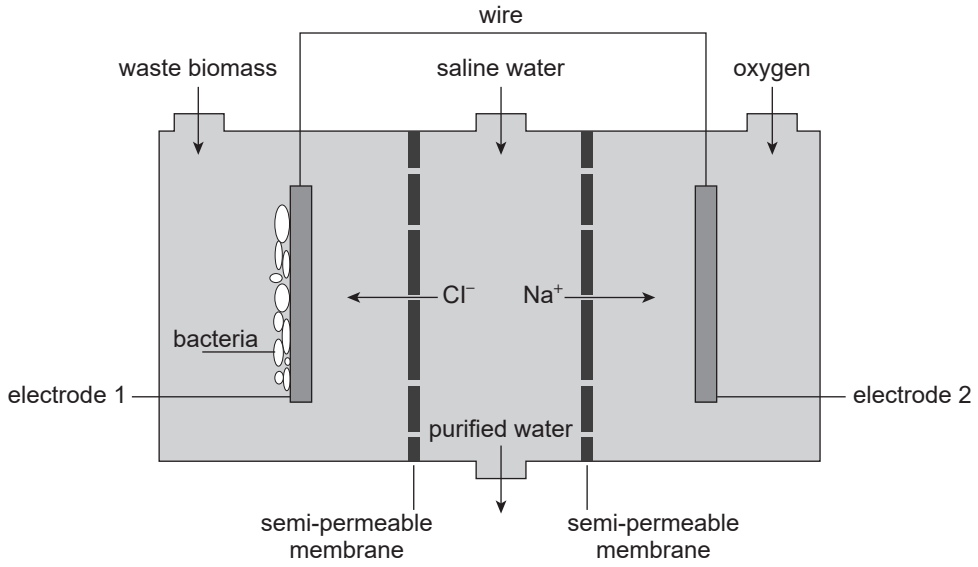
_____

_____ (2 marks)

(iii) Adapted MFCs can be used as an alternative to reverse osmosis for desalination of saline water.

A desalination MFC is constructed with a third compartment between the two electrodes of a standard MFC. This compartment is filled with saline water. The electrodes attract the ions in the saline water through semi-permeable membranes, thus filtering the ions from the water.

A diagram of a desalination MFC is shown below.



Source: adapted from a diagram by JHU Water Program in Mercer, J 2010, 'Microbial fuel cells: generating power from waste', *illumin*, viewed 22 August 2019, https://illumin.usc.edu

(1) Reverse osmosis is commonly used for desalination of saline water.

Explain why the production of potable water from saline water using reverse osmosis requires large amounts of energy.

_____

_____

_____

_____ (2 marks)

(2) State *one* reason why the energy requirement would be lower for the desalination MFC than for reverse osmosis.

_____

_____ (1 mark)

You may write on this page if you need more space to finish your answers to any of the questions in this question booklet. Make sure to label each answer carefully (e.g. 7(b)(ii)(1)(B) continued).

Chemistry data sheet

Metal activity

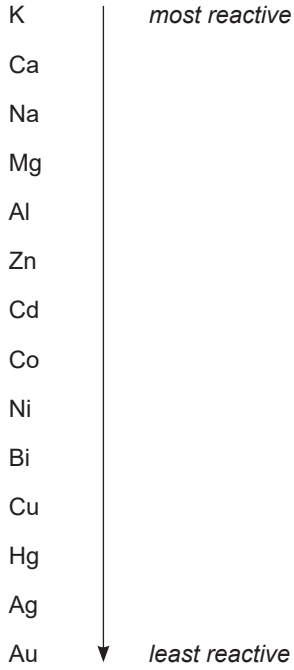


Table of SI prefixes

SI prefix	*Symbol*	*Value*
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Symbols of common quantities

amount of substance	n
mass	m
molar concentration	c
change in enthalpy	ΔH
molar mass	M
volume	V
heat energy	Q
specific heat capacity	c
temperature	T

Mathematical relationships

$$n = \frac{m}{M}$$

$$c = \frac{n}{V}$$

$$Q = mc\Delta T$$

$$\Delta H = \frac{Q}{n}$$

$$\text{pH} = -\log\left[\text{H}^{+}\right]$$

Periodic table of the elements

1 H hydrogen 1.008																	2 He helium 4.003
3 Li lithium 6.941	4 Be beryllium 9.012											5 B boron 10.81	6 C carbon 12.01	7 N nitrogen 14.01	8 O oxygen 16.00	9 F fluorine 19.00	10 Ne neon 20.18
11 Na sodium 22.99	12 Mg magnesium 24.31											13 Al aluminium 26.98	14 Si silicon 28.09	15 P phosphorus 30.97	16 S sulfur 32.06	17 Cl chlorine 35.45	18 Ar argon 39.95
19 K potassium 39.10	20 Ca calcium 40.08	21 Sc scandium 44.96	22 Ti titanium 47.90	23 V vanadium 50.94	24 Cr chromium 52.00	25 Mn manganese 54.94	26 Fe iron 55.85	27 Co cobalt 58.93	28 Ni nickel 58.70	29 Cu copper 63.55	30 Zn zinc 65.38	31 Ga gallium 69.72	32 Ge germanium 72.59	33 As arsenic 74.92	34 Se selenium 78.96	35 Br bromine 79.90	36 Kr krypton 83.80
37 Rb rubidium 85.47	38 Sr strontium 87.62	39 Y yttrium 88.91	40 Zr zirconium 91.22	41 Nb niobium 92.91	42 Mo molybdenum 95.94	43 Tc technetium (97)	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57[1] La lanthanum 138.9	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium (209)	85 At astatine (210)	86 Rn radon (222)
87 Fr francium (223)	88 Ra radium (226)	89[2] Ac actinium (227)	104 Rf rutherfordium (267)	105 Db dubnium (268)	106 Sg seaborgium (271)	107 Bh bohrium (272)	108 Hs hassium (270)	109 Mt meitnerium (276)	110 Ds darmstadtium (281)	111 Rg roentgenium (280)	112 Cn copernicium (285)	113 Nh nihonium (284)	114 Fl flerovium (289)	115 Mc moscovium (288)	116 Lv livermorium (293)	117 Ts tennessine (294)	118 Og oganesson (294)

[1]lanthanide series	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium (145)	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.0	71 Lu lutetium 175.0
[2]actinide series	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium (237)	94 Pu plutonium (244)	95 Am americium (243)	96 Cm curium (247)	97 Bk berkelium (247)	98 Cf californium (251)	99 Es einsteinium (252)	100 Fm fermium (257)	101 Md mendelevium (258)	102 No nobelium (259)	103 Lr lawrencium (262)