South Australian
Certificate of Education

1

Chemistry
2022

Question booklet 1

- Questions 1 to 3 (63 marks)
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on page 11 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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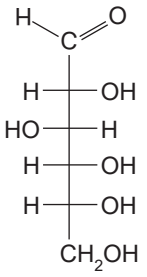
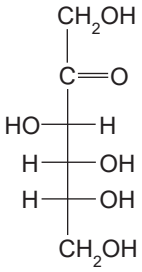
1. Soft drinks usually contain sugars and other additives.

(a) Sucrose is a disaccharide commonly found in soft drinks. The structural formulae of its monosaccharide units, glucose and fructose, are shown below.



Glucose



Fructose

(i) State why both glucose and fructose are classified as carbohydrates.

_____

_____

_____ (2 marks)

(ii) Write the molecular formula of sucrose.

_____ (1 mark)

(iii) When sucrose is digested, it is converted into its monosaccharides.

State the name of this type of reaction.

_____ (1 mark)

(iv) Some people need daily doses of an oral solution containing an enzyme that digests sucrose. This solution must be kept refrigerated.

The enzyme in one bottle of solution was thought to be inactive. A sample of this solution was added to some sucrose and shaken.

(1) Explain which one of Tollens reagent or acidified potassium dichromate solution should be used to identify whether the sucrose was converted into its monosaccharides.

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_____ (3 marks)

(2) Explain *one* reason why the enzyme may be inactive.

_____

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_____ (2 marks)

(b) A sample of one soft drink was analysed using HPLC. A polar mobile phase and a non-polar stationary phase were used.

The retention times under these conditions of three additives are shown in the table below.

Additive	*Retention time (min)*
saccharin	0.93
caffeine	2.37
benzoic acid	4.78

(i) Use the data in the table to identify and explain which of the three additives is the most polar.

_____

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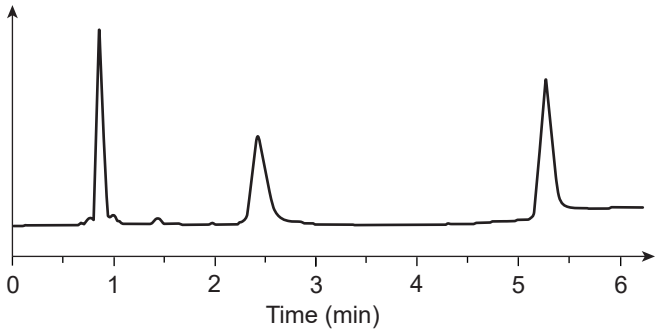
_____ (3 marks)

(ii) The chromatogram below was obtained from the analysis of the soft drink.



Identify which *one* of the three additives (saccharin, caffeine, or benzoic acid) was *not* present in the soft drink.

_____ (1 mark)

(iii) The Australian standard for the maximum concentration of caffeine allowed in soft drinks is 145 ppm. One 375 mL can of soft drink was analysed and found to contain 36.4 mg of caffeine.

Using a calculation, determine whether the concentration of caffeine in the soft drink conforms to the Australian standard.

(3 marks)

(c) Benzoic acid, a preservative, is often added to drinks in its salt form, sodium benzoate.

(i) Complete the equation for the reaction of benzoic acid with sodium hydrogencarbonate to form sodium benzoate.

(2 marks)

(ii) Suggest why benzoic acid is added to the soft drink in its salt form, rather than in its molecular form.

_____ (1 mark)

(iii) The concentration of sodium benzoate in one soft drink was determined using volumetric analysis.

All of the sodium benzoate in a 20.0 mL sample of this soft drink was converted to benzoic acid. The benzoic acid was made into an aqueous solution with a volume of 100.0 mL.

A 25.0 mL sample of the benzoic acid solution was titrated with 0.0010 mol L^{-1} standardised NaOH solution. Benzoic acid and sodium hydroxide react in a 1:1 ratio. The average titre was 5.05 mL.

(1) Calculate the concentration, in mol L^{-1}, of sodium benzoate in this soft drink. Give your answer to the appropriate number of significant figures.

(4 marks)

(2) The molar mass of sodium benzoate is 144.11 g.

Calculate the concentration in %w/v, of sodium benzoate in this soft drink.

(2 marks)

2. Chlorine and bromine are elements in the same group of the periodic table and so they have similar chemical properties.

(a) State the chemical property of chlorine and bromine that enables them to act as a water disinfectant.

_____ (1 mark)

(b) When bromine is dissolved in water, an equilibrium is established as shown in the equation below.

$$Br_2 + H_2O \rightleftharpoons H^+ + Br^- + HOBr$$

(i) State the colour of bromine in solution.

_____ (1 mark)

(ii) Explain, in terms of the equilibrium, why the colour of this solution fades as the pH is increased.

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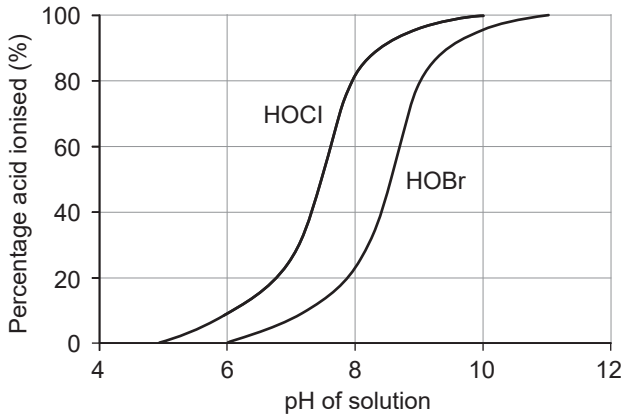
_____ (4 marks)

(c) Both HOCl and HOBr ionise in solution. The percentage ionisation of the two acids as the pH is increased is shown in the graph below.



(i) Calculate the hydroxide ion concentration, in mol L^{-1}, in a solution of pH 8.4.

(2 marks)

(ii) Use evidence from this graph to explain which acid, HOCl or HOBr, is the weaker acid.

(3 marks)

3. Global biodiesel production is increasing because biodiesel is replacing diesel fuel produced from fossil fuels.

(a) Diesel obtained from fossil fuels is a mixture of compounds, including $C_{18}H_{38}$ and $C_{14}H_{30}$. Incomplete combustion occurs during the combustion of diesel in air, resulting in the production of carbon (soot).

Explain why more soot is produced during the combustion of $C_{18}H_{38}$ than during the combustion of $C_{14}H_{30}$.

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_____ (2 marks)

(b) Explain why the combustion of biodiesel contributes less to global warming than the combustion of diesel from fossil fuels.

_____

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_____ (3 marks)

(c) Biodiesel is also a mixture of compounds.

(i) Write the formula of *one* biodiesel molecule made from stearic acid, $C_{17}H_{35}COOH$.

_____ (1 mark)

(ii) The molecular formula of another biodiesel molecule is $C_{13}H_{24}O_2$.

Write a balanced equation for the complete combustion of $C_{13}H_{24}O_2$.

(2 marks)

(d) The table below contains information about a sample of diesel and a sample of biodiesel.

Fuel sample	*Energy density* (MJ kg^{-1})	*Density* (kg L^{-1})
diesel	45	0.85
biodiesel	38	0.88

Use the data in the table above to calculate the volume, in L, of biodiesel required to produce the same amount of energy as produced by the complete combustion of 60 L of diesel.

(3 marks)

(e) Oxides of nitrogen are produced during combustion of both diesel and biodiesel in vehicles.

(i) Catalytic converters are part of the exhaust system in vehicles.

Write an equation that shows how catalytic converters reduce the quantity of *one* oxide of nitrogen produced during combustion.

(2 marks)

(ii) Explain why it is desirable to reduce the quantities of nitrogen oxides generated by motor vehicles. Include at least *one* equation to illustrate your answer.

(6 marks)

(iii) Modern catalytic converters are composed of a porous ceramic material coated with a very thin layer of aluminium oxide containing dispersed platinum nanoparticles that act as the catalyst.

Explain *one* possible reason why the platinum catalyst is present as nanoparticles.

_____

_____

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_____ (2 marks)

(f) Hazelnuts have been proposed as a source of biodiesel because hazelnut crops require less fertiliser than other commonly used biofuel crops.

Explain how excess fertilisers in waterways cause environmental problems.

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_____ (4 marks)

(g) Peanut crops can also be grown for biodiesel production. The roots of the peanut plant contain nitrogen-fixing bacteria that supply the plant with its nitrogen requirements.

Describe how these bacteria supply nitrogen to the plant.

_____

_____

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_____ (2 marks)

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. 1(c)(iii)(1) continued).

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Chemistry
2022

Question booklet 2

- Questions 4 to 6 (57 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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4. Bromine is produced industrially for use in the manufacture of a variety of products.

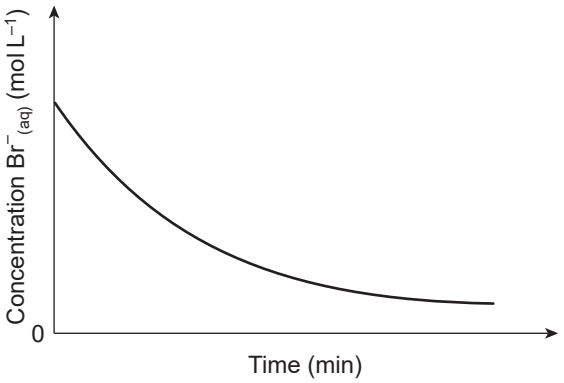
(a) The large-scale production of bromine usually involves chlorine gas being bubbled through a naturally occurring aqueous solution containing bromide ions. The reaction equation is shown below.

$$2Br^-_{(aq)} + Cl_{2(g)} \longrightarrow 2Cl^-_{(aq)} + Br_{2(g)}$$

(i) Using subshell notation, write the electron configuration of a bromide ion.

_____ (2 marks)

(ii) The concentration of Br^- as the reaction proceeds is shown in the graph below.



On the axes above, draw another curve to show how the concentration of Br^- would change if a more concentrated solution of Br^- was used, under the same conditions.

(2 marks)

(b) Bromine can also be produced by electrolysis of molten compounds such as magnesium bromide.

(i) Explain whether bromine is formed at the anode or at the cathode in the electrolysis of molten magnesium bromide.

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_____ (3 marks)

(ii) Identify the product that is formed at the other electrode in the electrolysis of molten magnesium bromide.

_____ (1 mark)

(iii) Explain *one* benefit to a manufacturer of producing bromine industrially from aqueous solutions containing bromide ions rather than from molten compounds.

_____

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_____ (2 marks)

(c) Halons are compounds containing bromine that are very effective in extinguishing fires. Over time, some halons produce the compound $COBr_2$, which decomposes into Br_2 and CO, as shown in the equation below.

$$COBr_{2(g)} \rightleftharpoons CO_{(g)} + Br_{2(g)}$$

This endothermic decomposition reaction was investigated by placing 1.00 mol of $COBr_2$ into an empty 5.00 L flask at 77°C and sealed. After equilibrium had been established, analysis showed that 0.60 mol of bromine was present in the flask.

(i) State whether the enthalpy value of this reaction is greater than or less than zero.

_____ (1 mark)

(ii) Calculate the value of K_c for the reaction at 77°C.

(4 marks)

(iii) Explain the effect on the value of K_c for this reaction if the temperature is increased.

_____

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_____ (3 marks)

(d) Although halons are greenhouse gases, they are approved for use in fire extinguishers in the aviation industry until 2024. In 2013, a group of aviation experts began an investigation to consider and recommend less harmful chemicals to replace halons. The group documented information from chemical production industries, chemical engineers, materials scientists, research institutes, regulatory agencies, and other organisations. An appropriate replacement chemical was finally selected after consideration of more than 30 different criteria related to firefighting performance, physical properties, environmental impacts, health and safety, and production requirements.

With reference to the science as a human endeavour key concept of 'Communication and Collaboration', explain how this investigation could benefit society.

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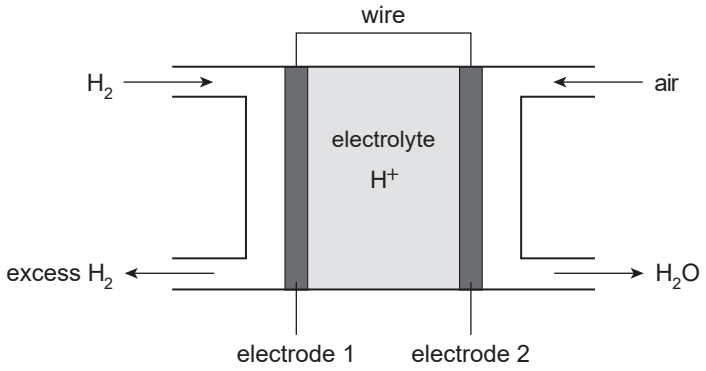
_____ (4 marks)

5. High-speed trains in many parts of Europe and Asia are now powered by hydrogen fuel cells.

(a) A diagram of a hydrogen fuel cell is shown below.

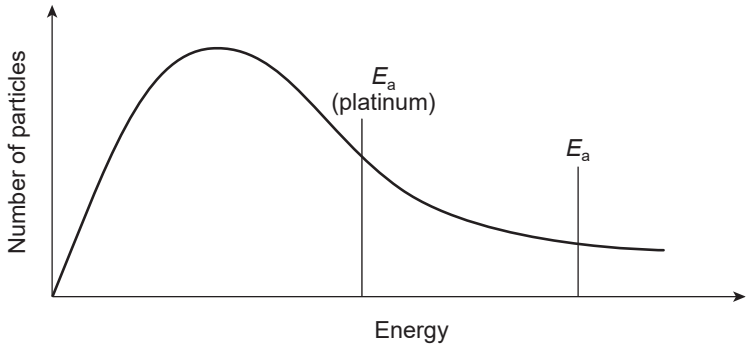


(i) Complete the half-equation for the reaction at electrode 2.

(2 marks)

(ii) Platinum is incorporated into the electrode materials of the fuel cell.

The activation energies for the reaction at electrode 2, with and without platinum, are marked on the diagram below, which shows the energy distribution of reactant particles at electrode 2.



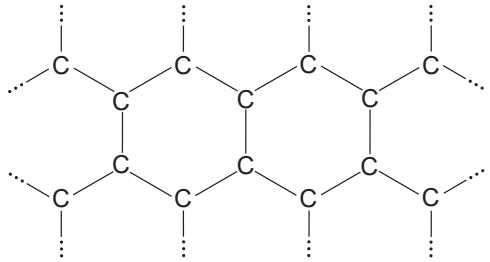
Explain how the diagram demonstrates that platinum is a catalyst for the reaction at electrode 2.

(3 marks)

PLEASE TURN OVER

(b) The hydrogen for the fuel cells in high-speed trains is stored under pressure. The storage tanks are made of composite materials consisting of synthetic polymers embedded with carbon fibre.

The structure of a section of a carbon fibre is shown below.



(i) Suggest *one* reason for using carbon fibre in this composite material.

_____ (1 mark)

(ii) Most carbon fibre is made from polyacrylonitrile, PAN, derived from petroleum. Carbon fibre can also be made from rayon derived from cellulose in wood. The two production pathways are shown below.

petroleum → propene → PAN → carbon fibre

wood → cellulose → rayon → carbon fibre

Describe *one* advantage of using rayon rather than PAN to make carbon fibre.

_____

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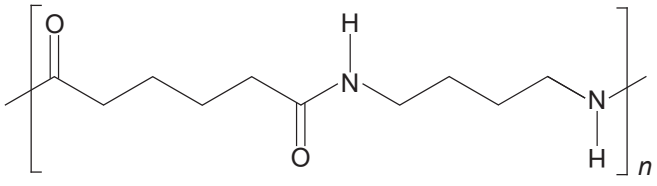
_____ (3 marks)

(iii) Nylon can be used as the synthetic polymer in the composite material used for a hydrogen storage tank. The structural formula of one nylon polymer is shown below.



(1) State the type of polymerisation used to make this polymer.

_____ (1 mark)

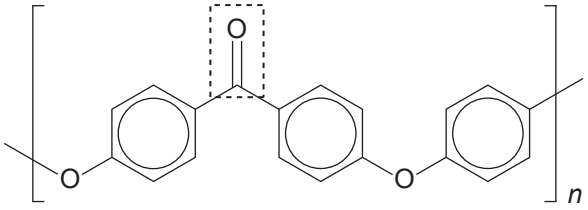
(2) Draw the structural formula of the diamine monomer used to make this polymer.

(1 mark)

(3) Name this diamine monomer.

_____ (2 marks)

(iv) The structural formula of another thermoplastic polymer being investigated for use in composite materials is shown below.



Name the functional group indicated by the dashed box on the diagram.

_____ (1 mark)

(v) Explain *one* difficulty with recycling composite materials.

_____

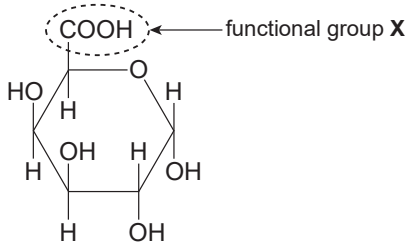
_____

_____

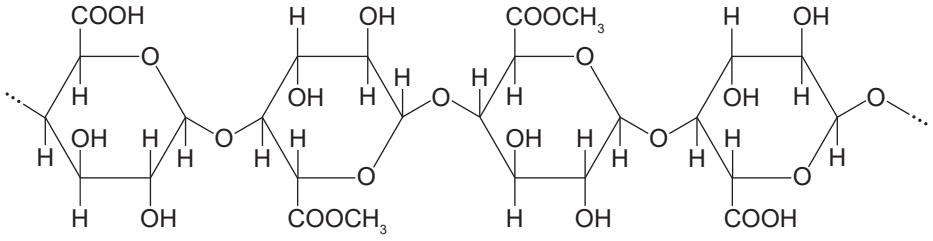
_____ (2 marks)

6. Pectin, a polysaccharide, is a structural component in the cell walls of vegetables such as green beans.

(a) Pectin polymer chains are made from monomers of galacturonic acid. The structural formula of galacturonic acid is shown below.



In some monomer units, functional group **X** reacts with compound **Y** to form a modified functional group. A section of a pectin polymer chain, with some modified monomer units, is shown in the diagram below.



State the name of compound **Y**.

_____ (1 mark)

(b) Different types of interactions can occur between pectin polymer chains.

(i) Sections of two adjacent polymer chains are shown in diagram **A** below.

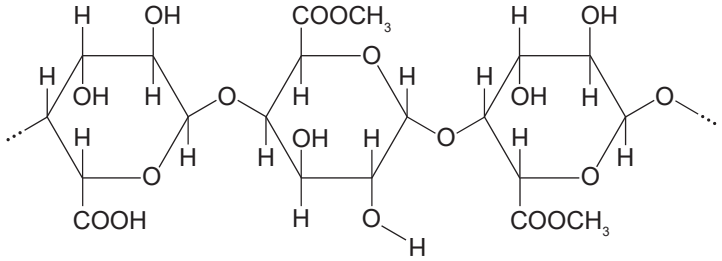
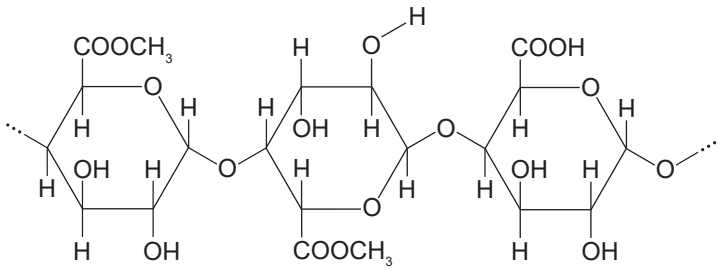


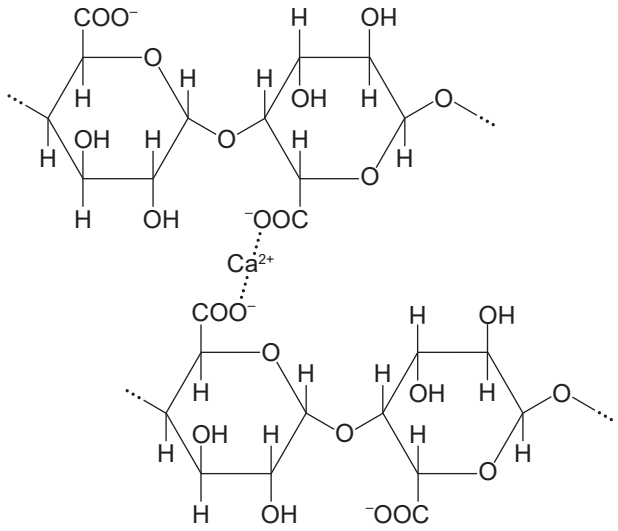
Diagram **A**



*On diagram **A**,* draw *one* hydrogen bond that forms between the two chains, using appropiate notation. (2 marks)

(ii) Another type of interaction can occur between Ca^{2+} and pectin polymer chains, as shown in diagram **B** below.

Diagram **B**



(1) State whether the pH of the solution surrounding the pectin in diagram **B** would be higher or lower than that in diagram **A**.

_____ (1 mark)

(2) Name the type of interaction shown in diagram **B**.

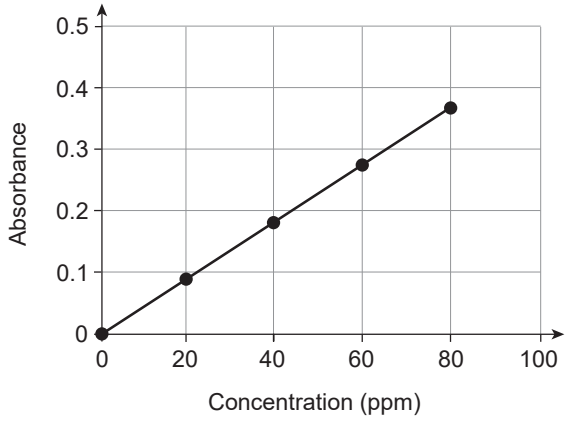
_____ (1 mark)

(3) State whether the type of interaction in diagram **B** is stronger or weaker than the type of interaction in diagram **A**.

_____ (1 mark)

(c) When green beans are cooked, pectin is released and the beans become less crunchy. The cooking time is affected by the concentration of Ca^{2+} in the cooking water. As the concentration of Ca^{2+} increases, the cooking time increases.

(i) One sample of tap water used for cooking beans was analysed using AAS. The concentration of Ca^{2+} in the sample was determined using the calibration graph shown below.



(1) The absorbance of the sample was 0.23.

Using the calibration graph, determine the concentration, in ppm, of Ca^{2+} in the sample.

_____ (1 mark)

(2) A second sample of tap water, from a different source, was analysed using the same spectrometer. The measured absorbance was 0.72.

Explain how the concentration of Ca^{2+} in the second sample could be accurately determined.

_____

_____

_____

_____ (2 marks)

(3) The wavelength of light selected for the analysis of Ca^{2+} was 422.7 nm.

Explain why this wavelength of light was used.

_____

_____

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_____

_____ (3 marks)

(ii) One way to decrease the concentration of Ca^{2+} in tap water, and hence reduce the cooking time for green beans, is to use a water softener.

(1) Sodium zeolite, $Na_2Al_2Si_2O_8$, is commonly used in water softeners.

Write the formula of the aluminosilicate anion in this zeolite.

_____ (1 mark)

(2) Explain how the concentration of Ca^{2+} in tap water decreases as the water passes over sodium zeolite.

_____

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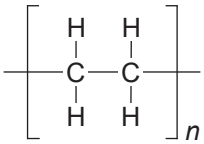
_____ (3 marks)

(iii) Another method of cooking green beans is to steam them in a plastic bag made of polyethene. The structural formula of polyethene is shown below.



(1) Explain whether a polyethene bag is likely to be biodegradable.

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_____ (2 marks)

(2) State *one* reason why it is desirable that the plastic bag is biodegradable.

_____

_____ (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. 6(c)(i)(2) continued).

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)

Chemistry data sheet

Metal activity

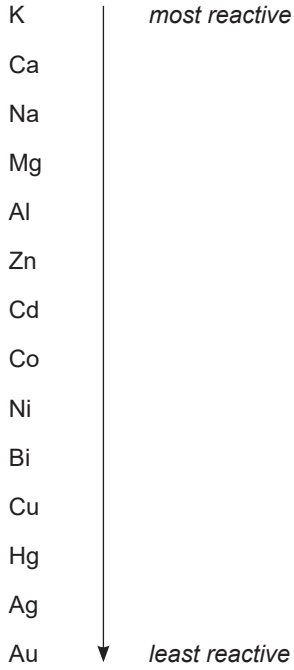

Table of SI prefixes

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

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

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

$$Q = mc\Delta T$$

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

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