South Australian
Certificate of Education

1

Chemistry
2018

Question booklet 1

- (Questions 1 to 4) 59 marks
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on page 15 if you need more space
- Allow approximately 60 minutes

Examination information

Materials
- Question booklet 1 (Questions 1 to 4)
- Question booklet 2 (Questions 5 to 8)
- SACE registration number label

Reading time
- 10 minutes
- You may begin writing during this time
- You may begin using an approved calculator during this time

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

Total marks 120

Government
of South Australia

Attach your SACE registration number label here

SACE
BOARD
OF SOUTH
AUSTRALIA

Remove this page from the booklet by tearing along the perforations.

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)

Metal activity

Li	*most reactive*
K	
Ca	
Na	
Mg	
Al	
Zn	
Cd	
Co	
Ni	
Cu	
Hg	
Pt	*least reactive*

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

Magnitude of physical constants

Avogadro's number	6.02×10^{23} mol^{-1}
heat capacity of water	4.18 J g^{-1} K^{-1}

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}

Mathematical relationships

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

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

$$Q = mC\Delta T$$

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

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

The examination questions begin on page 6.

1. Traces of different organic compounds contribute to the flavour of tomato juice. Three of these compounds are 2-methylbutanal, methyl salicylate, and phenylalanine.

(a) (i) Draw the structural formula of 2-methylbutanal.

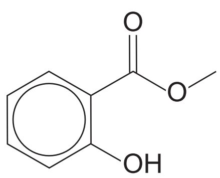
(2 marks)

(ii) The mass of 2-methylbutanal in a 10 mL sample of tomato juice is 1.22×10^{-7} g.

Calculate the concentration, in ppb, of 2-methylbutanal in this sample.

(3 marks)

(b) The structural formula of methyl salicylate is shown below.



Methyl salicylate can undergo both acidic hydrolysis and alkaline hydrolysis.

(i) Acidic hydrolysis of methyl salicylate produces an acid and another compound.

Name the other compound.

____ (1 mark)

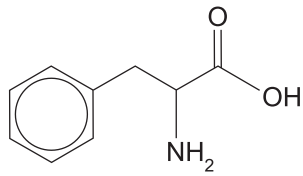
(ii) Identify a suitable reagent for the alkaline hydrolysis of methyl salicylate.

____ (1 mark)

(iii) Identify *one* way in which the products of hydrolysis of methyl salicylate differ when alkaline conditions, rather than acidic conditions, are used.

____ (1 mark)

(c) The structural formula of phenylalanine is shown below.



(i) Identify *two* features of the structure of phenylalanine that classify it as an amino acid.

____

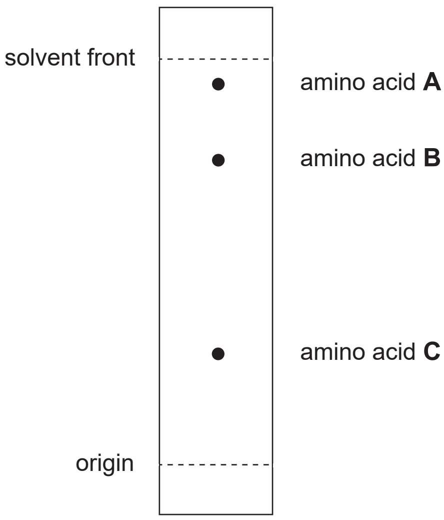
____ (2 marks)

(ii) Tomato juice is acidic.

Draw *one* possible structure of phenylalanine in tomato juice.

(1 mark)

(iii) Thin-layer chromatography was used to identify which of three amino acids (**A**, **B**, and **C**) was phenylalanine. The chromatogram produced is represented below.



The R_F value of phenylalanine for the conditions used in this separation is 0.75.

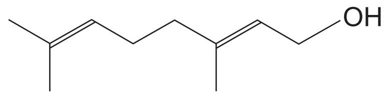
Identify and explain which of amino acids **A**, **B**, and **C** is phenylalanine.

____

____

____ (2 marks)

2. Geraniol is a compound that contributes to the aroma of rose oil. The structural formula of geraniol is shown below.



(a) When a mixture containing acidified potassium dichromate solution and geraniol is warmed, a reaction occurs and a colour change is observed.

(i) Name the functional group in geraniol that causes this colour change.

____ (1 mark)

(ii) State the colour change that is observed.

____ (2 marks)

(b) Geraniol reacts with propanoic acid to form geranyl propanoate, a food flavouring.

(i) Name the functional group formed in this reaction.

____ (1 mark)

(ii) Identify the other product formed in this reaction.

____ (1 mark)

(iii) Draw the structural formula of geranyl propanoate.

(2 marks)

(c) A sample of rose oil was analysed using gas chromatography.

Explain how the components of rose oil are separated as they travel through the column in the chromatograph.

____

____

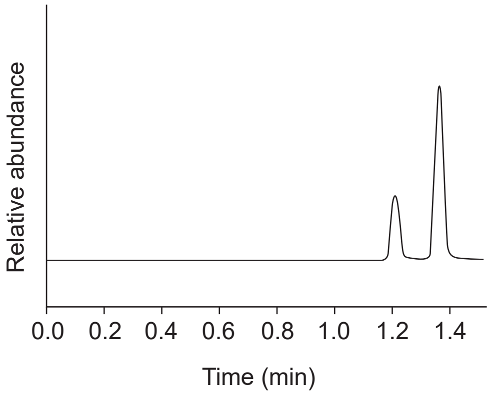
____

____

____

____ (3 marks)

(d) A sample of geraniol was analysed for purity, using a gas chromatograph. The diagram below represents the chromatogram obtained.



State, with a reason, whether or not this sample of geraniol is pure.

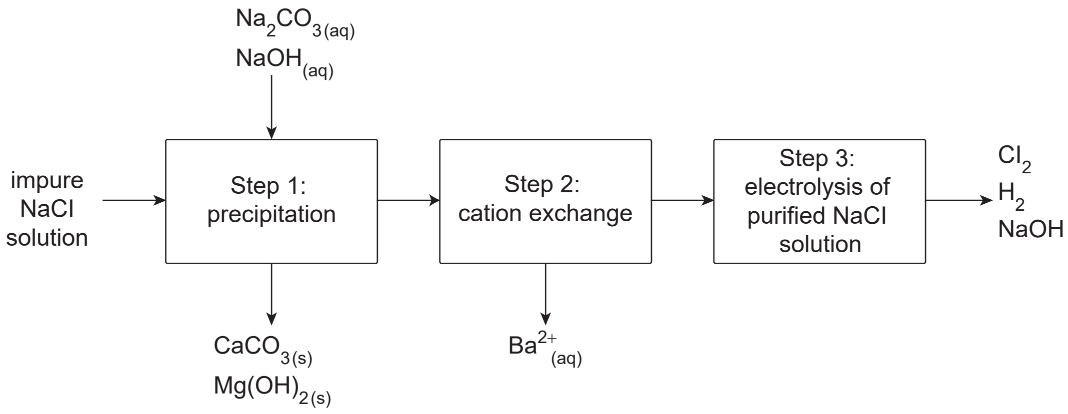
____

____

____ (2 marks)

3. Chlorine, Cl_2, is produced industrially on a large scale, and is used to manufacture a variety of other chemicals.

(a) The flow chart below shows the three main steps in the production of Cl_2.



(i) Referring to the flow chart, identify *two* raw materials used in the production of Cl_2.

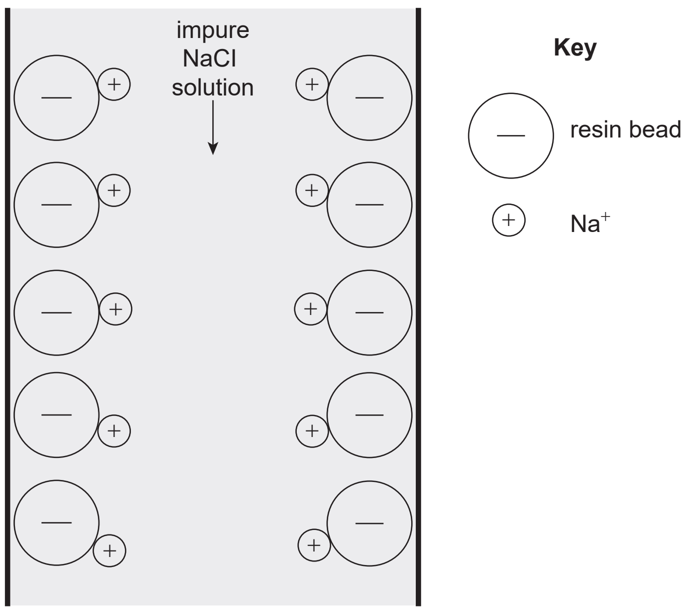
____

____ (2 marks)

(ii) Write an ionic equation for the precipitation reaction in Step 1 that produces $CaCO_{3(s)}$.

(2 marks)

(iii) Cation exchange is used in Step 2 to remove unwanted $Ba^{2+}_{(aq)}$ from the impure NaCl solution. A section of the cation-exchange column is shown in the diagram below.



With reference to the diagram of the cation-exchange column, explain how cation exchange removes unwanted $Ba^{2+}_{(aq)}$ from the impure NaCl solution.

(3 marks)

(iv) (1) Write the half-equation for the production of Cl_2 during electrolysis in Step 3.

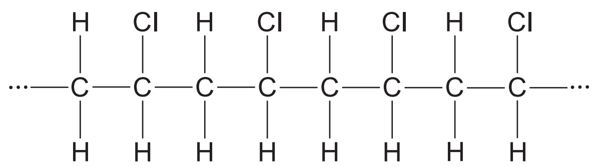
(2 marks)

(2) State whether Cl_2 will be produced at the anode or at the cathode.

(1 mark)

(b) Cl_2 reacts with hydrocarbons to produce a monomer. This monomer is used to produce polyvinyl chloride, PVC.

A section of a PVC polymer is shown below.



(i) Name the type of polymerisation that produces PVC.

(1 mark)

(ii) PVC is a thermoplastic polymer.

(1) Explain why thermoplastic polymers are recyclable.

(2 marks)

(2) Describe *one* advantage to the environment of recycling, rather than discarding, unwanted PVC.

____

____

____

____ (2 marks)

(c) Cl_2 forms two compounds with phosphorus: PCl_3 and PCl_5.

When PCl_5 is heated, the following reaction occurs:

$$PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$$

In an experiment to determine the K_c value for this reaction, 0.200 mol of PCl_5 was placed in an empty flask, which was then sealed and heated to a certain temperature. Two trials, A and B, were undertaken under the same conditions.

(i) Write the K_c expression for this reaction.

(1 mark)

(ii) In trial A, a 2.00 L flask was used. At equilibrium, 0.060 mol of PCl_3 was present.

(1) Calculate the concentrations of PCl_5, PCl_3, and Cl_2 at equilibrium.

(3 marks)

(2) Calculate the K_c value for this reaction at this temperature.

(1 mark)

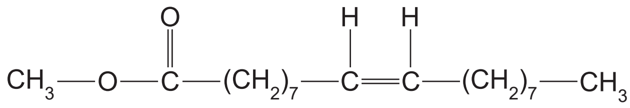
(iii) In trial B, a 1.00 L flask was used.

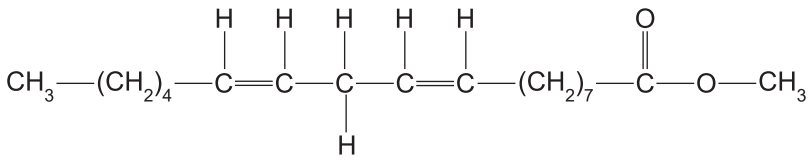
State how the K_c value obtained in trial B would compare with the K_c value obtained in trial A.

____ (1 mark)

4. Canola plants are grown to produce canola oil, which can be used to make biodiesel.

(a) The structural formulae of two molecules that are present in biodiesel made from canola oil are shown below.





Using this information, draw the structural formula of *one* triglyceride that could be found in canola oil.

(2 marks)

(b) Fertiliser used to grow canola plants can run off the land and into water bodies.

Explain why water bodies that contain high concentrations of fertiliser may no longer be able to sustain aquatic life.

(4 marks)

(c) During the combustion of biodiesel in motor vehicle engines, NO is produced and emitted to the air.

(i) Explain why a high temperature in the engine is required in order for NO to be produced.

(2 marks)

(ii) A catalytic converter contains a honeycomb structure of platinum-coated microscopic channels. As NO flows over the surfaces of the channels, most of it is converted to N_2.

(1) Explain, with the aid of an equation, how catalytic converters lead to the formation of less photochemical smog.

(3 marks)

(2) Researchers have recently designed a more effective arrangement of the catalyst, which not only uses 80% less platinum but also increases the active surface area of the channels. The researchers have set up a company to manufacture catalytic converters that use this new arrangement of the catalyst.

With reference to the key concept of application, explain — in terms of science as a human endeavour — *one* benefit of this new arrangement of the catalyst.

(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. 3(b)(ii)(1) continued).

South Australian Certificate of Education

Chemistry
2018

Question booklet 2

- (Questions 5 to 8) 61 marks
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on page 14 if you need more space
- Allow approximately 60 minutes

2

Government of South Australia

Copy the information from your SACE label here

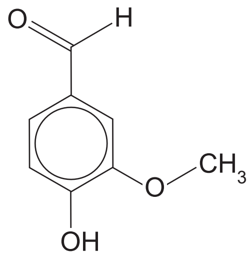
SEQ	FIGURES						CHECK LETTER	BIN

SACE
BOARD
OF SOUTH
AUSTRALIA

5. Many foods and beverages purchased by consumers contain synthetic components.

(a) Vanilla flavouring may contain synthetic vanillin.

The structural formula of vanillin is shown below.



(i) On the structural formula above, circle the aldehyde group. (1 mark)

(ii) Draw the structural formula of the alcohol that can be oxidised to produce vanillin.

(2 marks)

(iii) Describe how Tollens' reagent can be used to distinguish a sample of vanillin from a sample of the alcohol referred to in part (a)(ii).

____

____

____

____ (2 marks)

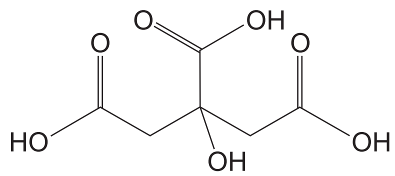
(b) Synthetic lemonade can be made by dissolving citric acid, sucrose, and carbon dioxide in water.

(i) The pH of lemonade can vary between 2.5 and 3.5, depending on how much citric acid is used.

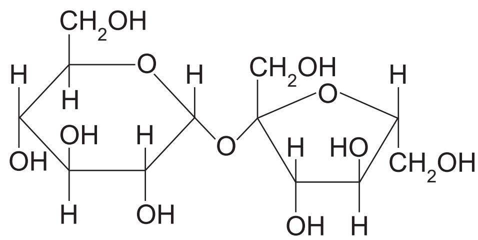
Calculate the difference in concentration of H^+, in mol L^{-1}, between a lemonade of pH 2.5 and a lemonade of pH 3.5.

(2 marks)

(ii) The structural formulae of citric acid and sucrose are shown below.



citric acid



sucrose

With reference to the structural formulae of citric acid and sucrose, explain why citric acid contributes to the low pH of lemonade but sucrose does ***not***.

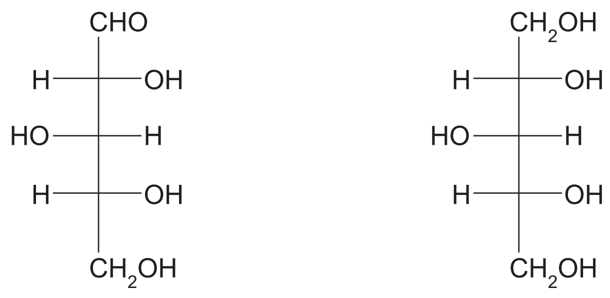
(3 marks)

(iii) The reaction between carbon dioxide and water also affects the pH of lemonade.

Write a chemical equation for the reaction between carbon dioxide and water.

(2 marks)

(c) Xylitol is a synthetic sweetener that is manufactured commercially by reacting xylose with hydrogen. The structural formulae of xylose and xylitol are shown below.



xylose **xylitol**

(i) One advertisement claims that both xylose and xylitol are carbohydrates.

Explain why this claim is false.

____

____

____

____

____

____ (2 marks)

(ii) The reaction between xylose and hydrogen occurs under high pressure.

Explain, in terms of collision theory, why high pressure is used for this reaction.

____

____

____

____

____

____ (3 marks)

6. Bioethanol can be made from the cellulose in wood pulp.

(a) The first step in the production of bioethanol is the hydrolysis of cellulose (a polysaccharide), to produce glucose.

Write an equation for the hydrolysis of cellulose to produce glucose.

(2 marks)

(b) The second step in the production of bioethanol is the fermentation of glucose.

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

(2 marks)

(ii) State how yeast increases the rate of fermentation of glucose.

____

____ (1 mark)

(iii) Bioethanol produced from fermentation contains water. The high solubility of water in ethanol means that more than one distillation is needed in order to remove the water from the bioethanol.

Explain why water is highly soluble in ethanol.

____

____

____

____ (2 marks)

Credit will be given for answers to part (c) that are coherent and contain only relevant information.

(2 marks)

(c) Bioethanol is added to unmodified petrol to produce a modified petrol known as 'gasohol'.

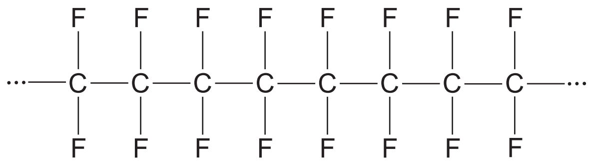
Discuss advantages and disadvantages of using gasohol, rather than unmodified petrol, in motor vehicles.

(6 marks)

7. PFAS chemicals (a group of fluorinated organic compounds) do not occur naturally in the environment.

(a) The first PFAS chemical produced was polytetrafluoroethene (PTFE), which has been used as a non-stick surface coating on cookware to make cooking and cleaning easier.

The structure of a section of PTFE is shown below.



polytetrafluoroethene (PTFE)

(i) Draw the structural formula of the monomer that is used to produce PTFE.

(1 mark)

(ii) The carbon–fluorine bonds in PTFE are polar because of the high electronegativity of the fluorine atom. Hence the fluorine atoms at the surface of PTFE molecules are partially charged.

(1) State whether this partial charge is positive or negative.

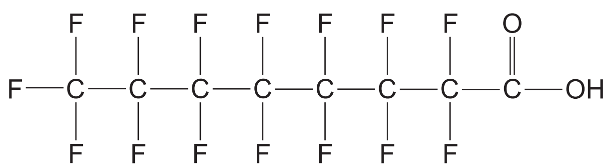
____ (1 mark)

(2) State why PTFE molecules are non-polar.

____

____ (1 mark)

(b) Perfluorooctanoic acid (PFOA) is another PFAS chemical, and has been used since the 1950s in the production of PTFE. The structural formula of PFOA is shown below.



perfluorooctanoic acid (PFOA)

(i) The PFOA molecule has a polar head and a long, non-polar tail.

State the name of the functional group that forms the polar head.

____ (1 mark)

(ii) Suggest *one* use for the anionic form of PFOA.

____ (1 mark)

(c) Since their introduction in the 1950s, PFAS chemicals have been used worldwide in industrial and consumer products. They are resistant to degradation because their carbon–fluorine bonds are very strong. Consequently, PFAS chemicals have been detected worldwide in soil, water, and living organisms.

In the 1990s, more sensitive analytical techniques became available, which enabled the detection of PFAS chemicals in blood. This led to the detection of PFAS chemicals in the blood of the general human population.

International research suggests that PFAS chemicals may have damaging effects on human health, but the evidence is not yet conclusive. PFAS chemicals take a very long time to leave the human body.

The major sources of PFAS chemical exposure in humans are not very well understood, and are still being investigated by scientists in Australia and other countries. It seems that humans are most likely exposed to PFAS chemicals through PFAS-contaminated water and food.

The key concepts of science as a human endeavour are:

- communication and collaboration
- development
- influence
- application and limitation.

With reference to one or more of these key concepts, describe *two* ways in which this short history of PFAS chemicals exemplifies science as a human endeavour.

____

____

____

____

____

____

____

____

____

____

____

____ (4 marks)

8. The presence of some metal cations in tap water can lead to undesirable outcomes.

(a) In some locations, high concentrations of Ca^{2+} are found in tap water.

(i) (1) State the term used to describe water that has a high concentration of Ca^{2+}.

____ (1 mark)

(2) Explain *one* undesirable outcome of washing clothes with water that has a high concentration of Ca^{2+}.

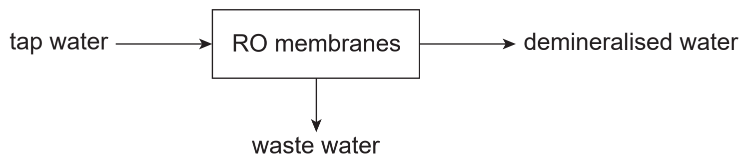
____

____

____

____ (2 marks)

(ii) The simplified flow chart below shows how the process of reverse osmosis, RO, removes metal cations such as Ca^{2+} from tap water.



Explain how RO removes metal cations such as Ca^{2+} from tap water.

____

____

____

____

____

____ (3 marks)

(b) The presence of metal cations such as Fe^{3+} in tap water can lead to discoloration of clothes during washing.

(i) Four electron configurations (**A**, **B**, **C**, and **D**) are shown below.

A: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$

B: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3\ 4s^2$

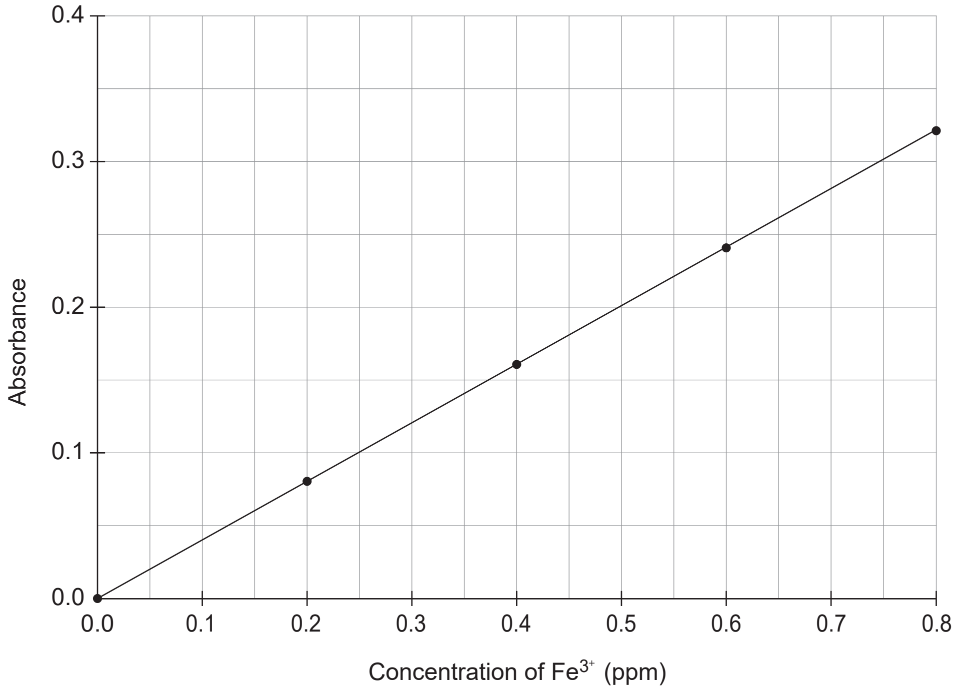
C: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$

D: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9\ 4s^2$

Identify which of **A**, **B**, **C**, and **D** represents the electron configuration of Fe^{3+} in its lowest energy state.

______________________________ (1 mark)

(ii) An analytical technique was used to determine the concentration of Fe^{3+} in a tap water sample. The calibration graph prepared for this determination is shown below.



(1) Write the full name of the analytical technique that was used.

______________________________ (1 mark)

(2) The absorbance of the tap water sample was found to be 0.1.

Using the graph above, determine the concentration of Fe^{3+} in the tap water sample, in ppm.

______________________________ (1 mark)

(iii) One active ingredient in some products that are used to remove stains from clothes is hydrogen peroxide, H_2O_2.

(1) A student carried out a titration to determine the concentration of H_2O_2 in one stain remover. The following procedure was used:

Step 1 — preparation of dilute solution of stain remover

10.00 mL of stain remover was pipetted into a 100.0 mL volumetric flask, which was then filled to the calibration line with distilled water.

Step 2 — titration

20.00 mL samples of the dilute solution prepared in Step 1 were titrated with a 0.0415 mol L^{-1} permanganate solution until a permanent pink colour remained. The average titre was 17.35 mL.

The equation for the reaction is shown below.

$$2MnO_4^- + 5H_2O_2 + 6H^+ \longrightarrow 2Mn^{2+} + 5O_2 + 8H_2O$$

Credit will be given for the correct use of significant figures in answers to part (A). (1 mark)

(A) Calculate the number of moles of MnO_4^- that reacted.

(2 marks)

(B) Calculate the number of moles of H_2O_2 in 20.00 mL of the dilute solution of stain remover.

(2 marks)

(C) Calculate the concentration of H_2O_2, in mol L^{-1}, in the undiluted stain remover.

(2 marks)

(2) The concentration of H_2O_2 determined by the student was lower than the concentration stated on the bottle of stain remover. H_2O_2 decomposes during storage.

(A) State whether the decomposition of H_2O_2 during storage would lead to a systematic error or a random error in this titration.

____ (1 mark)

(B) The student decided to investigate whether exposure to light of different intensities affects the rate of decomposition of H_2O_2.

The student set up five flasks and placed each flask in a separate box. Each box contained a light of a different intensity. All flasks contained 20 mL of H_2O_2 and were left in their boxes for 1 week.

Identify *one* other factor that needs to be kept constant in all five trials, and explain why this factor needs to be kept constant.

____

____

____

____

____

____ (3 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. 8(b)(iii)(1)(A) continued).