GAN ENG SENG SCHOOL

Preliminary Examination 2024

CANDIDATE NAME	
CLASS	
INDEX NUMBER	

CHEMISTRY

6092/02

Paper 2

21 August 2024

1 hour 45 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.
Write your answers in the spaces provided.

Section B
Answer **one** question.
Write your answers in the spaces provided.

The number of marks is given in brackets [ ] at the end of each question or part question.
A copy of the Periodic Table is printed on page **23**.

The use of an approved scientific calculator is expected, where appropriate.

For Examiner's Use	
Section A	**70**
Section B Q9 Q10 *Circle where appropriate	**10**
Total	**80**

Section A

Answer **all** questions.

1 The equations below show reactions involving elements **A** to **E**.

Element **A**: $2\ \mathbf{A} + 2\ H_2O \rightarrow 2\ \mathbf{A}OH + H_2$

Element **B**: $\mathbf{B}O_2 + 2\ NaOH \rightarrow Na_2\mathbf{B}O_3 + H_2O$

Element **C**: $\mathbf{C}_2 + 2\ Br^- \rightarrow 2\ \mathbf{C}^- + Br_2$

Element **D**: $\mathbf{D} + Cu^{2+} \rightarrow \mathbf{D}^{2+} + Cu$

Element **E**: $\mathbf{E}_2O_3 + 6\ H^+ \rightarrow 2\ \mathbf{E}^{3+} + 3\ H_2O$

Each letter represents an element found in **Period 3** of the Periodic Table (sodium to argon). The letters do not represent the actual symbols of the elements.

(a) Identify elements **A** to **E**.

A ……

B ……

C ……

D ……

E …… [5]

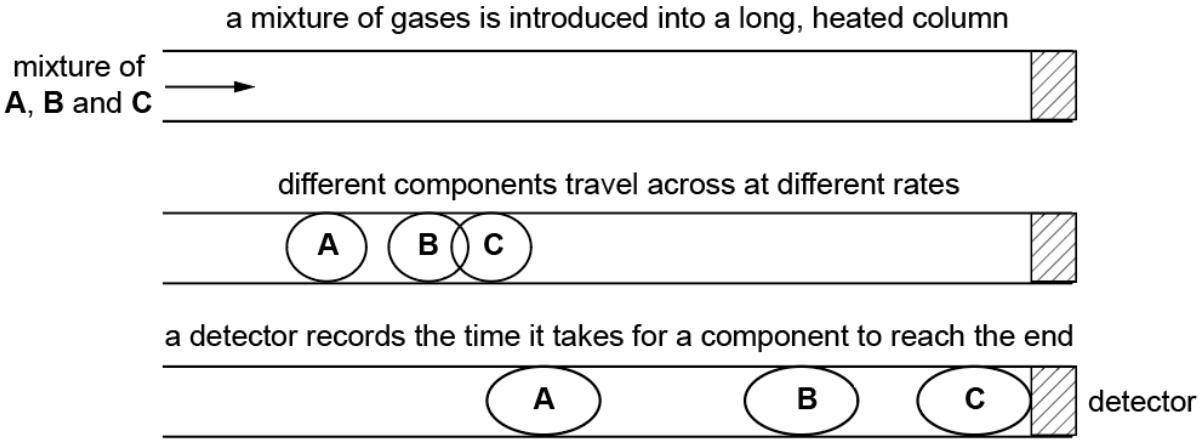
(b) Classify each element as having undergone oxidation, reduction or neither. Put a tick (✓) in each row.

element	undergone oxidation	undergone reduction	neither oxidised nor reduced
A			
B			
C			
D			
E			

[3]

[Total: 8]

2 Gas chromatography can be used to separate a mixture of gases as shown below.



The retention time is the time it takes each component to travel through the column.

(a) The gases entering the column must be dry to avoid interference from water molecules.

Suggest how the gases may be dried.

…….. [1]

(b) Vegetable oils can be changed into bio-diesel for use in diesel engines.

Gas chromatography is used to identify the methyl esters in a sample of bio-diesel.

The table shows the retention time for three methyl esters.

methyl ester	M_r	retention time / min
lauric	214	1.6
palmitic	270	3.1
stearic	298	3.9

One factor affecting retention time is the rate of diffusion.

(i) The data in the table suggests a correlation between the relative molecular mass and the retention time.

Describe this correlation.

……

…… [1]

(ii) The experiment is repeated with the column at a higher temperature.

Suggest and explain how this will affect the retention times.

……

……

……

……

……

…… [3]

(c) Unlike gas chromatography, paper chromatography compares R_f values instead of retention times.

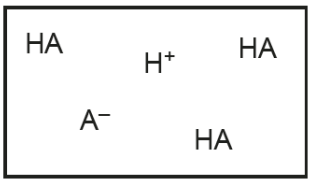
Besides temperature, state one factor that affects R_f values.

…….. [1]

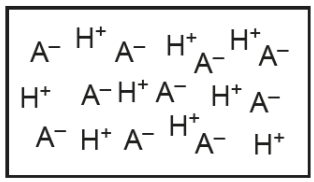
[Total: 6]

3 The diagrams show four different types of acid solutions.
The acid molecule is represented as HA. The ions formed in solution are represented as H^+ and A^-.

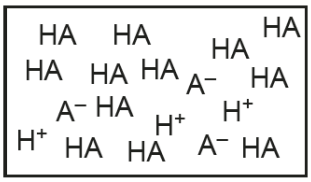
1



2



3



4

(a) State which diagram represents a dilute solution of a weak acid. Explain your answer.

……..

……..

……..

…….. [3]

(b) Explain why sulfuric acid is not represented by the diagrams above.

……..

…….. [2]

(c) Equal volumes of ethanoic acid and hydrochloric acid of the same concentration was allowed to react completely with magnesium.

State, with a reason, whether the volume of hydrogen gas produced will differ.

…….. [1]

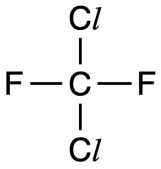
(d) An unknown bottle is suspected to contain dilute sulfuric acid.
Outline a chemical test that can be used to confirm this.

……..

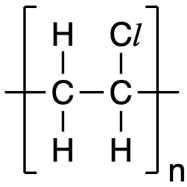
…….. [2]

[Total: 8]

4 Two chlorine-containing organic molecules shown below are known to cause harm to the environment.



dichlorodifluoromethane (CFC-12)



polyvinyl chloride (PVC)

(a) In the presence of sunlight, CFC-12 decomposes into chlorine atoms, which deplete the ozone layer by causing the breakdown of ozone in a two-step reaction.

$$Cl + O_3 \rightarrow ClO + O_2$$

$$ClO + O_3 \rightarrow 2\ O_2 + Cl$$

(i) Explain why the depletion of the ozone layer would be undesirable to humans.

……

……

…… [2]

(ii) Use the equations to write an overall equation for the reaction.

…… [2]

(iii) Explain how the equations show that chlorine atoms act as a catalyst for the breakdown of ozone.

…… [1]

(iv) Chlorine exists as two stable isotopes, with chlorine-35 (^{35}Cl) reacting faster with ozone than chlorine-37 (^{37}Cl). Studying the ^{37}Cl to ^{35}Cl ratio helps scientists model the rate of ozone depletion more accurately.

Complete Table 4.1 to show the number of subatomic particles in each isotope of chlorine.

Table 4.1

isotope	^{35}Cl	^{37}Cl
number of electrons		
number of neutrons		
number of protons		

[2]

(b) **(i)** Draw the structure of the monomer used to make polyvinyl chloride (PVC).

[1]

(ii) Describe one pollution problem caused by non-biodegradable plastics such as polyvinyl chloride (PVC).

…….

…….

……. [1]

(iii) The best way of disposing of plastic waste is recycling to form new plastics. State an advantage of recycling plastics made from petroleum.

…….

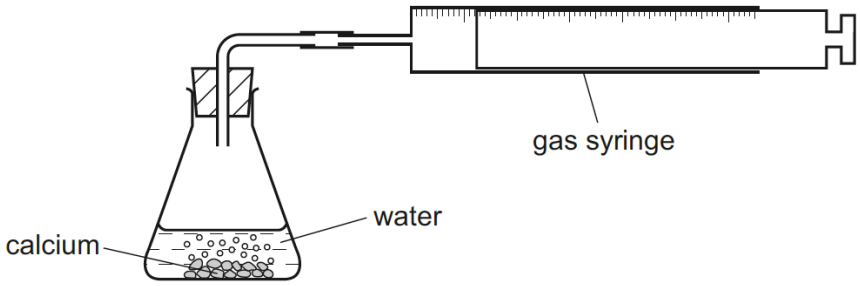
……. [1]

[Total: 10]

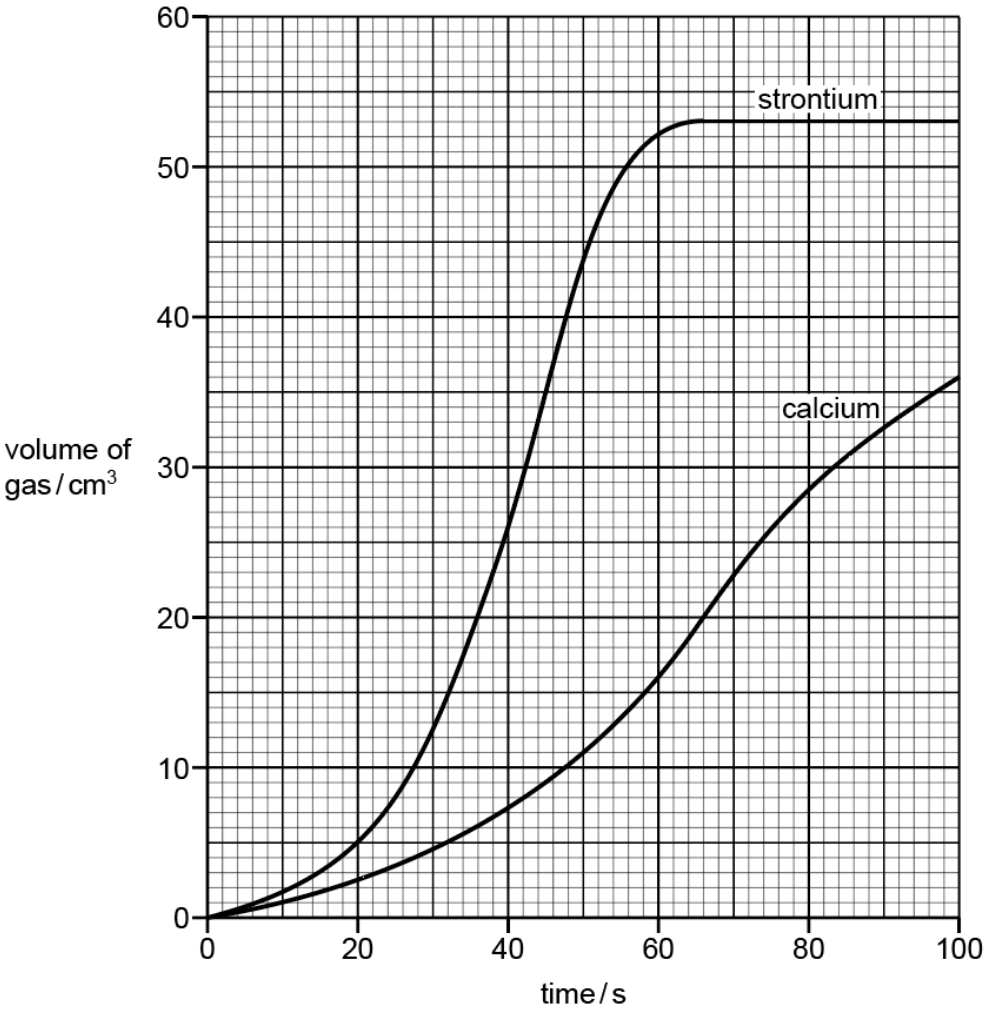
5 The reaction between metals and water can be studied using the apparatus shown.

A fixed mass of calcium was allowed to react completely with water.

The volume of gas given off was recorded at fixed time intervals during the reaction.



The experiment was repeated using strontium but keeping all the conditions the same.
The graph obtained from the results is shown below.



(a) Explain how the graph shows that strontium is more reactive than calcium.

……..

…….. [1]

(i) Calculate the average rate of reaction, in cm^3/s, for the reaction between strontium and water.

average rate of reaction = ……. cm^3/s [1]

(ii) Explain how the graph shows that the reaction between calcium and water was **not** complete at 100 seconds after the reaction started.

…….

……. [1]

(b) The solution formed at the end of the reaction between strontium and water was tested with Universal Indicator. The indicator turned purple.

Explain this observation with the aid of a chemical equation.

……..

……..

…….. [3]

(c) The electrolysis of a molten electrolyte is one method of extracting a metal from its ore. Other methods are the electrolysis of an aqueous solution and the reduction of the oxide by carbon.

Explain why these last two methods cannot be used to extract strontium from strontium oxide.

electrolysis of an aqueous solution ……

…….

reduction of the oxide by carbon ……

……. [2]

[Total: 8]

6 Ammonia is manufactured by the Haber Process.
The equation for the reaction is shown.

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

The economics of this process require that as much ammonia as possible is made as quickly as possible.

The percentage yield of ammonia varies with conditions.

pressure / atm	100	200	300	400
% ammonia at 300 ºC	45	65	72	78
% ammonia at 500 ºC	9	18	25	31

(a) Describe how hydrogen is obtained for the Haber process.

…….. [1]

(b) Use the electronic structure of nitrogen to explain why the formula of ammonia is NH_3 not NH_4.

……..

……..

…….. [2]

(c) Describe the effect of changing temperature on the percentage yield of ammonia.

…….. [1]

(d) **(i)** Explain, in terms of particles, what happens to the rate of this reaction when the pressure is increased.

…….

…….

…….

…….

…….

……. [3]

(ii) State one other advantage of using a high pressure.

……. [1]

(iii) The conditions actually used are 200 atmospheres, 450 ºC and finely divided iron catalyst.

Suggest one reason why a pressure higher than 200 atmospheres is not used in the Haber process.

…….

……. [1]

(e) State what happens to the unreacted nitrogen and hydrogen.

…….. [1]

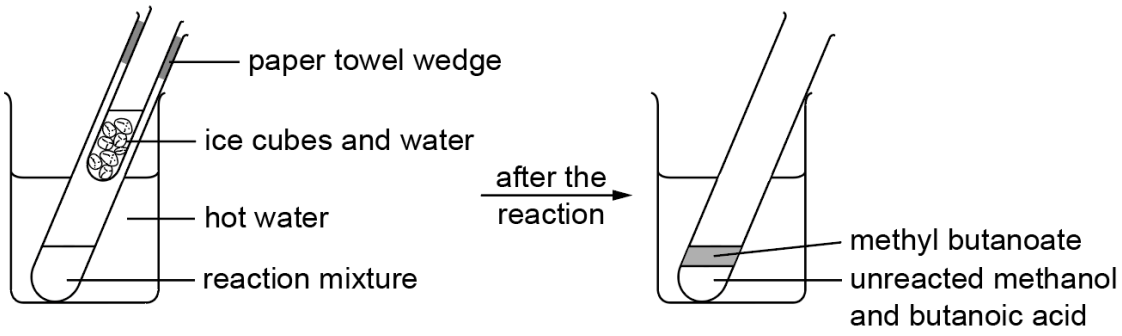
[Total: 10]

7 Chemists use esterification reactions to create various pleasant-smelling esters, which are essential components of many artificial and natural flavours.

One such ester, methyl butanoate, is a key contributor to the characteristic aroma of raspberries. It is made by reacting methanol with butanoic acid.

$$\underset{(M_r = 32)}{\text{methanol}} + \underset{(M_r = 88)}{\text{butanoic acid}} \rightleftharpoons \underset{(M_r = 102)}{\text{methyl butanoate}} + \underset{(M_r = 18)}{\text{water}}$$

The diagram of the experiment is shown below.



(a) Draw the full structural formula of methyl butanoate.

[1]

(b) Suggest the purpose of the test-tube containing ice cubes and water in the set-up.

……..

…….. [1]

(c) Based on the information above, explain why an ester can be separated from the mixture using a separating funnel.

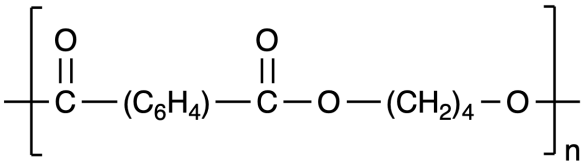
…….. [1]

(d) In an experiment, 2.0 g of methanol was reacted with excess butanoic acid to produce methyl butanoate. However, only 1.0 g of methyl butanoate was isolated after purification.

Calculate the percentage yield of the reaction.

percentage yield = ……. % [3]

(e) Polyethylene terephthalate is a polyester used in fibres for clothing, containers for liquids and food.



polyethylene terephthalate (PET)

Outline **one** similarity and **one** difference in the formation of methyl butanoate and polyethylene terephthalate from their respective reactant molecules.

……..

……..

……..

…….. [2]

[Total: 8]

8 How carbon dioxide affects the oceans

The oceans act as a carbon sink, absorbing much of the CO_2 produced from burning fossil fuels. When CO_2 dissolves in water, carbonic acid, H_2CO_3 is formed.

$$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

H_2CO_3 dissociates in water to form bicarbonate ions, HCO_3^- and hydrogen ions, H^+. When atmospheric CO_2 levels increase, more CO_2 to dissolves into ocean waters, decreasing the pH of the oceans.

$$H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$$

The ocean naturally contains carbonate ions, CO_3^{2-}, which shell-making marine organisms use to build their calcium carbonate shells. However, when the pH of the ocean decreases, the excess H^+ ions consume the CO_3^{2-} ions available to these organisms.

$$CO_3^{2-}(aq) + H^+(aq) \rightleftharpoons HCO_3^-(aq)$$

A Bjerrum plot (Fig 8.1) shows the percentage of each carbon-containing species at different pH.

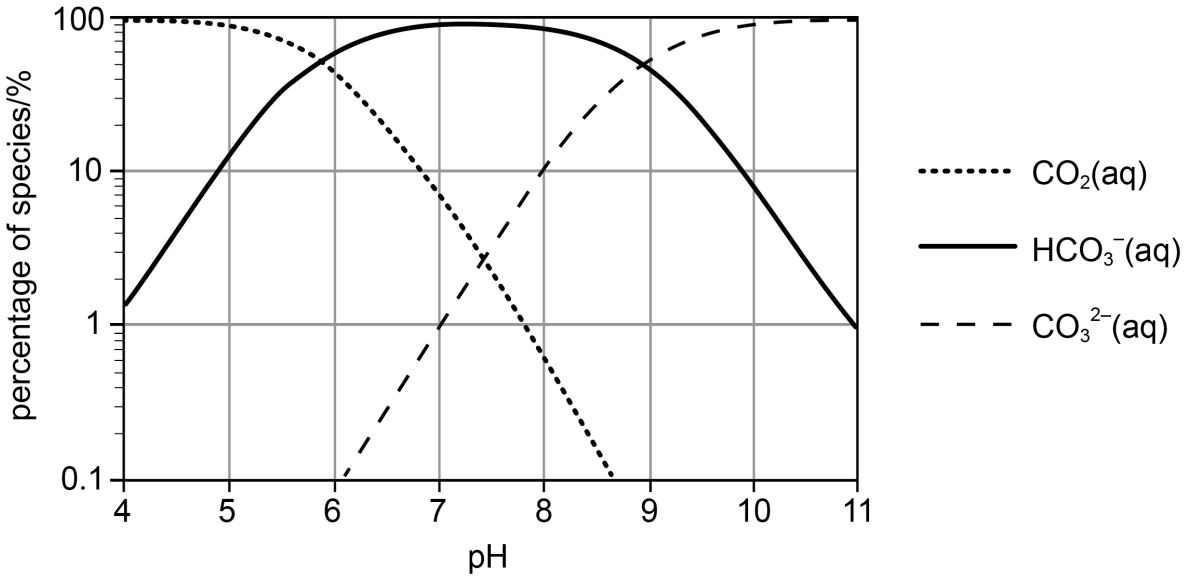


Fig. 8.1: Bjerrum plot

The uptake of CO_2 by seawater has led to the average ocean surface pH falling from 8.2 to 8.1 in the last 200 years. While this change may seem small, it represents an approximate increase of 30% in acidity. Besides far-reaching implications for marine creatures, there is a limit to the capacity of the oceans to absorb CO_2, unless the CO_2 is simultaneously removed.

Removing CO_2 from oceans

Singapore produces over 50 million tonnes of CO_2 annually. Scientists are exploring the use of electrolytic processes to remove CO_2 from the oceans to expand the ocean's capacity to absorb more CO_2. By 2025, the world's largest ocean-based CO_2 removal plant, dubbed the Equatic-1, will be built in Singapore. The facility can remove 10 tonnes of CO_2 per day from

seawater and the atmosphere. This will bring Singapore closer towards the target of achieving net zero emissions by 2050.

A scheme of the process used by Equatic-1 is shown in Fig. 8.2.

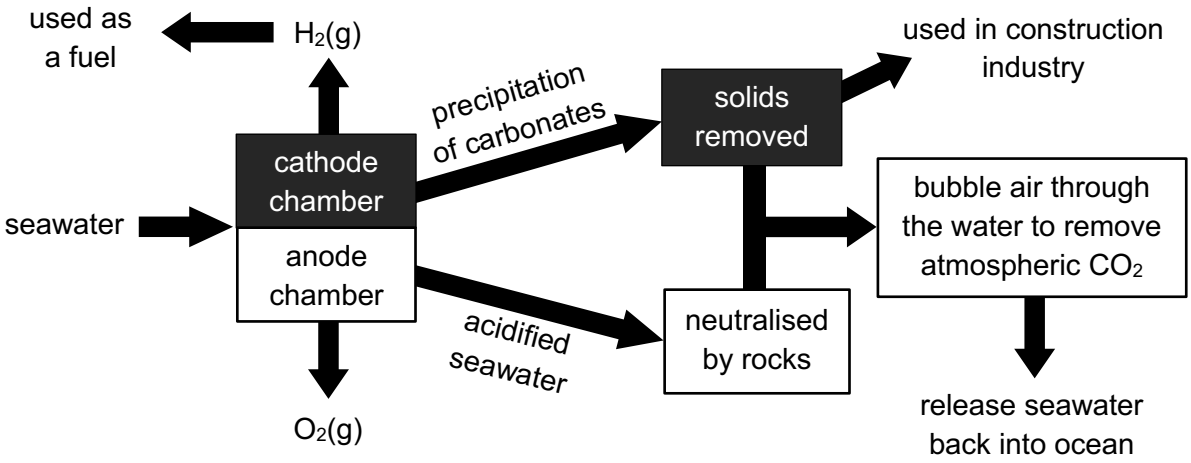


Fig. 8.2

Seawater from the adjacent PUB desalination plants enters the cathode and anode chambers where water is electrolysed and decomposed into oxygen and hydrogen.

In the cathode chamber, the water flows through a porous electrode. The electrode surface is continuously scraped with a blade that dislodges accumulated solids and re-exposes the mesh surface. These metal carbonates could potentially be used in the construction industry for land restoration, cement, or concrete.

The concentration of ions in seawater is shown in Table 8.3.

Table 8.3: Concentration of ions in seawater

cation	concentration (mg/dm^3)
Na^+	10600
Mg^{2+}	1260
Ca^{2+}	400
K^+	380

anion	concentration (mg/dm^3)
Cl^-	19000
SO_4^{2-}	2650
HCO_3^-	140
Br^-	65

The anode is covered with an oxygen evolution selective coating to ensure that oxygen gas is produced. As the mixture exiting the anode chamber is acidic, the natural alkalinity and composition of seawater is restored by dissolving alkaline rocks such as $Mg_2SiO_4(s)$ (forsterite) and $CaAl_2Si_2O_8(s)$ (anorthite) before releasing the seawater back into the ocean.

(a) Based on information in Fig. 8.1, arrange, in increasing order, the percentage of $CO_2(aq)$, $HCO_3^-(aq)$ and $CO_3^{2-}(aq)$ in naturally-occurring seawater.

…….. [1]

(b) Explain, with the aid of a half equation, why the pH increases at the cathode chamber during electrolysis.

……..

……..

…….. [2]

(c) Explain, using information in Fig. 8.1 and Table 8.3, why the increase in pH at the cathode would result in the precipitation of metal carbonates. You should identify the metal carbonates in your answer.

……..

……..

…….. [2]

(d) Deduce, using information from Table 8.3, the gas that would be produced in significant quantity in the anode chamber without the oxygen evolution selective coating. Explain your reasoning.

……..

……..

…….. [2]

(e) A silicate is a polyatomic anion consisting of silicon and oxygen, with the general formula $[SiO_{(4-x)}^{(4-2x)-}]_n$ where n is a whole number and $0 \leq x < 2$.

Show, using values of n and x, that forsterite and anorthite are silicates.

……..

……..

…….. [2]

(f) Discuss whether the Equatic-1 facility in Singapore would better manage the carbon cycle to result in human lifestyles becoming more environmentally sustainable.

……..

……..

……..

……..

……..

…….. [3]

[Total: 12]

Section B

Answer **one** question from this section.

9 Calcium nitrate, $Ca(NO_3)_2$, and ammonium nitrate, NH_4NO_3, are ionic compounds which are used to make fertilisers.

Fig. 9.1 shows how the ions are arranged in a solid, ionic compound.

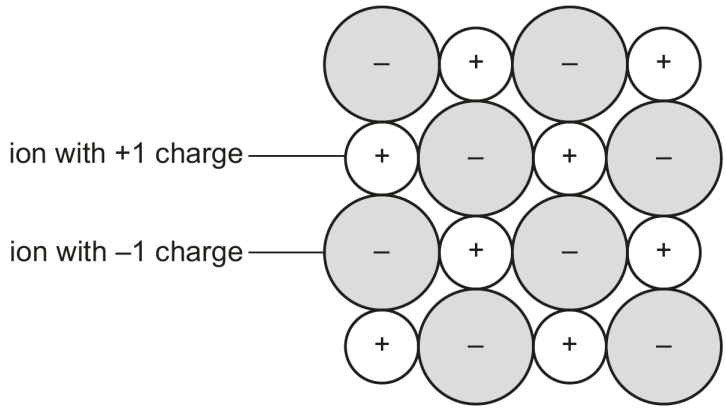


Fig. 9.1

(a) Give two reasons why Fig. 9.1 is a better representation for the ions in solid ammonium nitrate, NH_4NO_3, than the ions in solid calcium nitrate, $Ca(NO_3)_2$.

……..

……..

……..

…….. [2]

(b) In Fig. 9.1 the ions are shown far larger than they actually are.

Suggest one other reason why Fig. 9.1 does not accurately represent a solid ionic compound.

……..

…….. [1]

The overall energy changes that happen when solid fertilisers dissolve in water are related to bond breaking and bond forming processes.

Fig. 9.2 shows the process of a solid ionic compound dissolving in water.

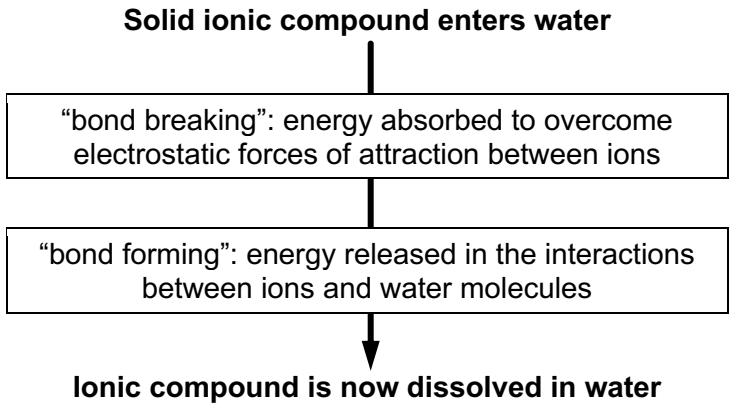


Fig. 9.2

Fig. 9.3 shows the overall energy changes when solid calcium nitrate and solid ammonium nitrate dissolve in water.

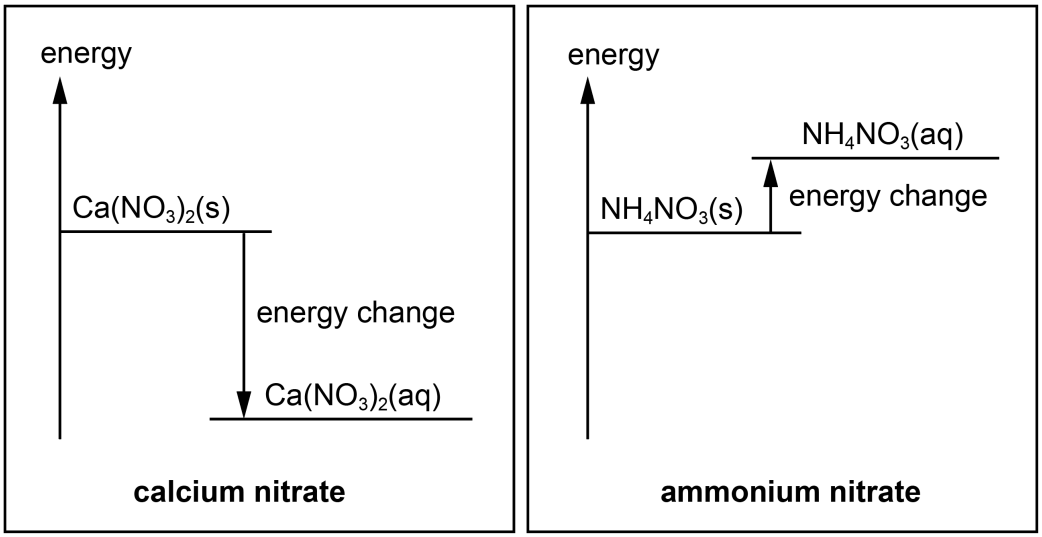


Fig. 9.3

(c) Using Fig. 9.2 and Fig. 9.3, describe and explain the differences in the overall energy changes when calcium nitrate and ammonium nitrate dissolve in water.

……..

……..

……..

……..

……..

……..

……..

…….. [4]

(d) **(i)** Describe the steps required to prepare a solution of calcium nitrate, starting with powdered calcium carbonate.

……

……

…… [2]

(ii) Ammonium nitrate can be prepared by the method of titration.

Suggest a suitable pair of reagents that react to produce ammonium nitrate.

…… [1]

[Total: 10]

10 The table shows information about some alkanes.

alkane	molecular formula	melting point / ºC	physical state at 25 ºC
methane	CH_4	–182	gas
propane	C_3H_8	–190	gas
butane	C_4H_{10}	–138	gas
octane	C_8H_{18}	–57	liquid
pentacontane	$C_{50}H_{102}$	93	solid

(a) **(i)** State the empirical formula of pentacontane.

……. [1]

(ii) The empirical formulae of methane and propane are the same as their molecular formulae.

Explain why.

…….

……. [1]

(b) Explain, in terms of structure and bonding, why the melting points of the alkanes are generally low.

……..

……..

…….. [2]

(c) A textbook has this description of a homologous series.

A homologous series contains compounds with similar structures, the same general formula and similar chemical properties. The compounds show a trend in physical properties down the series.

Use your own knowledge and the information in the table to explain how the alkanes match this description of a homologous series.

……..

……..

……..

……..

……..

……..

……..

…….. [4]

(d) Petrol companies 'crack' larger molecules like pentacontane to make smaller molecules such as octane.

Explain why 'cracking' makes the business more profitable and better for the environment.

……..

……..

……..

…….. [2]

[Total: 10]

End of paper

The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9		Key proton (atomic) number atomic symbol name relative atomic mass									5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	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 lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	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 –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

The Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}