Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination 2020
Year 6

H1 CHEMISTRY

8873/01

Paper 1 Multiple Choice

28 September 2020

1 hour

Additional Materials: Data Booklet

                   Optical Mark Sheet

INSTRUCTIONS TO CANDIDATES

1 Write your **name, index number** and **class** on this question paper and the OTAS Mark Sheet.

2 There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Optical Mark Sheet.

3 Each correct answer will score one mark. A mark will not be deducted for wrong answer.

4 Any rough working should be done in this booklet.

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

6 On the OTAS Mark Sheet, please shade the code as "Class/Index number".

For illustration only:

A student from class 6C99, with index number 02, should shade "9902".

This document consists of **12** printed pages and **0** blank page.

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1 Bones contain a complex mixture of calcium salts, protein and other materials. When a bone is strongly heated in a current of air, the only residue is calcium oxide.

From a sample of 65.0 g of bone, 27.0 g of calcium oxide were obtained.

What is the percentage by mass of calcium in the bone?

A 20.8%

B 29.7%

C 35.6%

D 41.5%

2 Which solution contains the biggest amount, in moles, of chloride ions?

A 20 cm^3 of 0.50 mol dm^{-3} NH$_4$Cl

B 70 cm^3 of 0.30 mol dm^{-3} NaCl

C 60 cm^3 of 0.20 mol dm^{-3} MgCl$_2$

D 100 cm^3 of 0.30 mol dm^{-3} CH$_3$CH$_2$Cl

3 F$_2$ reacts with BrO$_x^-$ ions in a 2:1 molar ratio to form F$^-$ and BrO$_4^-$ ions.

What is the value of x?

A 1

B 2

C 3

D 5

4 A disproportionation reaction is a reaction in which an element in a species undergoes both oxidation and reduction simultaneously.

Which of the following is **not** a disproportionation reaction?

A $3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$

B $H_2C_2O_4 \rightarrow H_2O + CO + CO_2$

C $H_2O + 2NO_2 \rightarrow HNO_2 + HNO_3$

D $2FeSO_4 \rightarrow Fe_2O_3 + SO_2 + SO_3$

5 *Use of the Data Booklet is relevant to this question.*

Assume that the elements in the fourth period show similar periodicity to those in the third period.

Selenium and bromine are in the fourth period of the Periodic Table.

Which statement is true?

1 The angle of deflection of Br^- is smaller than Se^- when beams of Br^- and Se^- are passed in an electric field.

2 The first ionisation energy of Se is smaller than its second ionisation energy.

3 The ionic radius of Br^- is smaller than that of Se^{2-}.

A	1, 2 and 3	**B**	1 and 3 only
C	2 and 3 only	**D**	2 only

6 Chromium has two stable isotopes, ^{52}Cr and ^{53}Cr.

Which statement is correct?

A $^{53}Cr^{2+}$ ion has fewer protons than $^{52}Cr^{3+}$ ion.

B The electronic configuration of $^{52}Cr^+$ is $[Ar]\ 3d^4\ 4s^1$.

C $^{52}Cr^{2+}$ ion has the same number of neutrons as $^{53}Cr^{3+}$ ion.

D $^{52}Cr^{2+}$ ion has more unpaired electrons than $^{53}Cr^{3+}$ ion.

7 Which species has the smallest bond angle?

A SF_6

B BrF_2^+

C IF_2^-

D CO_2

8   Nitrogen and carbon monoxide are simple molecules with boiling points 77 K and 82 K respectively.

     Which statement best explains the difference in their boiling points?

     A   Nitrogen is a non–polar molecule while carbon monoxide is a polar molecule.

     B   The nitrogen molecule has fewer σ and π bonds than the carbon monoxide molecule.

     C   The nitrogen molecule has greater surface area than the carbon monoxide molecule.

     D   The nitrogen molecule has fewer electrons than the carbon monoxide molecule.

9   Which of the following observations could be explained with reference to hydrogen bonding?

     A   The boiling point of butan–1–ol is 118 °C while the boiling point of methanol is 65 °C.

     B   Thermal stability of the hydrogen halides decreases in the order: HF > HCl > HBr > HI.

     C   Propanone and propanal mix completely at 20 °C.

     D   The boiling point of propan–1–ol is 97 °C while the boiling point of propanone is 56 °C.

10   T is an element in Period 3.

     Two test tubes are half–filled with water containing a few drops of universal indicator.

     The oxide of T is added to the first test tube while the chloride of T is added to the second test tube.

     The final colour in both test tubes is the same.

     What is element T?

     A   magnesium

     B   aluminium

     C   silicon

     D   phosphorus

11   Which element is most likely to have similar electronegativity as aluminium?

     A   boron   B   beryllium

     C   magnesium   D   calcium

8873/01

12   Group 1 elements form diatomic molecules in the gas phase.

Which molecule has the smallest dipole moment?

A   Li–Na

B   Li–K

C   Li–Rb

D   Li–Cs

13   The standard enthalpy change of formation of HCl and HI are -92 kJ mol^{-1} and $+26$ kJ mol^{-1} respectively.

Which statement accounts for the difference?

1   Chlorine has a greater first ionisation energy than iodine.

2   The activation energy for the reaction between H_2 and Cl_2 is much less than that between H_2 and I_2.

3   HI is thermally less stable than HCl.

A   1 and 2 only   B   2 and 3 only

C   1 only   D   3 only

14   Astatine lies below iodine in the Periodic Table. The properties of astatine can be predicted from the trends in the properties of Group 17 elements.

Which prediction is correctly made for astatine?

A   It is a viscous liquid at room temperature.

B   It is more electronegative than iodine.

C   C–At covalent bond is weaker than C–I covalent bond.

D   It oxidises iodide ions to iodine.

15 The reaction pathway diagram for a two–step reaction is shown below.

Step 1: **J** $\rightleftharpoons$ **K**

Step 2: **K** $\longrightarrow$ **L**
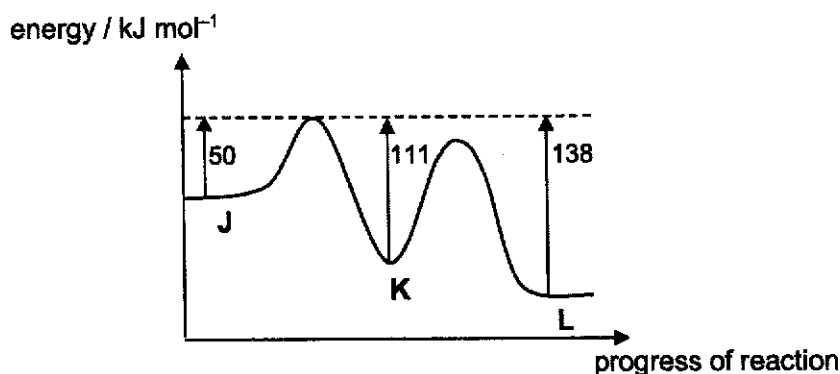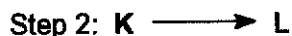
Which statement is correct?

A Step 2 is more exothermic than step 1.

B The enthalpy change for both the forward and backward reactions in step 1 is the same.

C The activation energy for the backward reaction in step 1 is 61 kJ mol^{-1}.

D The enthalpy change of reaction for the conversion of **J** to **L** is the sum of the enthalpy changes in step 1 and step 2.

16 Which equation represents a standard enthalpy change at 298 K?

A $C(g) + O_2(g) \rightarrow CO_2(g)$

B $Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$

C $2C(s) + 6H(g) \rightarrow C_2H_6(g)$

D $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

17 *Use of the Data Booklet is relevant to this question.*

When 0.86 g of ethanol burns under a container containing 300 g of water, the temperature of the water rises by 18 °C.

The enthalpy change of combustion of ethanol is –1367 kJ mol^{-1}.

What is the process efficiency of this reaction?

A 28%

B 48%

C 68%

D 88%

18   Substances **R**, **S** and **T** react according to the following equation:

$$R(aq) + 2S(aq) + T(aq) \rightarrow 2U(aq) + V(aq)$$

In investigations of this reaction, the following results were obtained.

What can be deduced from the information shown?

1   The order of reaction with respect to **R** is zero.

2   The order of reaction with respect to **S** is two.

3   The overall order of the reaction is two.

A	1, 2 and 3	**B**	1 and 2 only
C	2 and 3 only	**D**	1 only

19   Nitrogen gas reacts with hydrogen gas according to the following equation.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

Why is the rate of reaction slow at room temperature?

A   The activation energy of the forward reaction is high.

B   The activation energy of the forward reaction is low.

C   The equilibrium constant is very small.

D   The rate of the reverse reaction is greater than the rate of the forward reaction.

20 A radioactive element has two isotopes, **M** and **N**, with half–lives of 10 min and 30 min respectively. An experiment starts with 4 times as many atoms of **M** as of **N**.

Radioactive decay is a first–order reaction.

How long will it be before the number of atoms of **M** left equals the number of atoms of **N** left?

A 10 min

B 20 min

C 30 min

D 60 min

21 Iodine and cyclopentane, C_5H_{10}, react to form hydrogen iodide and cyclopentadiene, C_5H_6, in a reversible reaction as shown below.

$$2I_2(g) + C_5H_{10}(g) \rightleftharpoons 4HI(g) + C_5H_6(g)$$
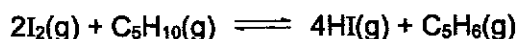
The equilibrium yield of C_5H_6 is higher at higher temperature.

Which statement is true?

A The presence of a suitable catalyst will speed up only the forward reaction.

B The forward reaction is an endothermic reaction.

C More hydrogen iodide will be produced when the four gases, at equilibrium, are compressed.

D The value of K_c will be larger when more iodine is introduced to the equilibrium mixture.

22 Consider the following equilibrium reaction:

$$3Fe(s) + 4H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$$
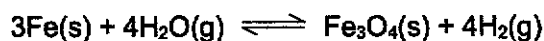
Which is the units for the equilibrium constant, K_c?

A $mol\ dm^{-3}$

B $mol^{-2}\ dm^6$

C $mol^4\ dm^{-12}$

D no units

23   The values of ionic product of water, K_w, at two different temperatures are given below.

temperature / °C	K_w / mol^2 dm^{-6}
25	1.00×10^{-14}
100	5.50×10^{-13}

One indicator with corresponding pH range is given below.

indicator	pH range	colour before pH range	colour at pH range	colour after pH range
Bromothymol Blue	6.0 – 7.6	yellow	green	blue

Which statement is true for water at the given temperature?

1   pH of water at 100 °C is less than 7.

2   Water is not a Brønsted–Lowry base at 100 °C.

3   The colour of Bromothymol Blue when mixed with water at 25 °C is green.

A   1, 2 and 3   B   2 only

C   1 and 3 only   D   3 only

24   Which is an example of an Arrhenius acid and Arrhenius base reaction?

A $2CH_3COOH(aq) + Ca(OH)_2(aq) \rightarrow Ca(CH_3COO)_2(aq) + 2H_2O(l)$

B $CO_2(aq) + 2NaOH(aq) \rightarrow Na_2CO_3(aq) + H_2O(l)$

C $2HCl(aq) + Na_2O(s) \rightarrow 2NaCl(aq) + H_2O(l)$

D $HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$

25 Ethene can be formed from bromoethane in two steps.

$$C_2H_5Br \xrightarrow{\text{step R}} C_2H_5OH \xrightarrow{\text{step S}} C_2H_4$$

Which statements about these steps are correct?

1   Step **R** involves substitution.

2   Step **S** involves elimination.

3   Hot aqueous H_2SO_4 is the reagent in Step **S**.

A 1 only	**B** 1 and 2 only
C 3 only	**D** 1, 2 and 3

26 How many σ and π bonds are present in compound **P**?

P

	number of σ bonds	number of π bonds
A	9	4
B	13	4
C	16	2
D	17	2

27 Compound **Q** is treated with an excess of lithium aluminium hydride.

Q
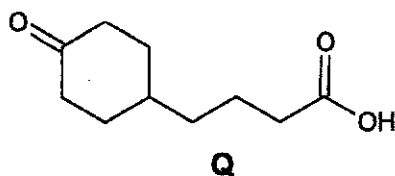
What is the structure of the organic product?

A

B

C

D
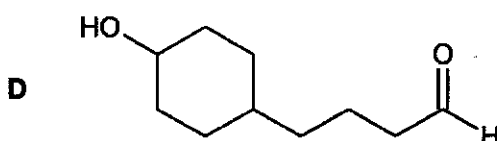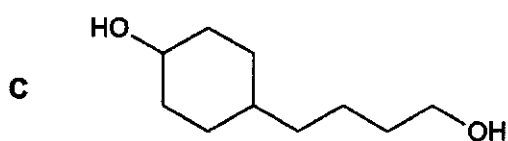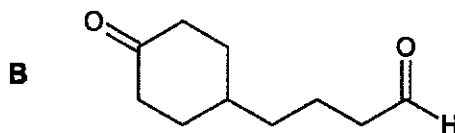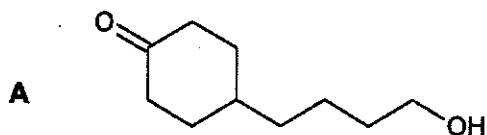
28 Compound **Z** can be hydrolysed by HCl(aq). The two products of this hydrolysis have the same empirical formula.

What could **Z** be?

A	$CH_3COCOCH_3$	B	$CH_3CO_2CH_2CH_3$
C	$CH_3CO_2CH_2CH_2COOH$	D	$CH_3CH_2CH(OH)CH(OH)CH_2CH_3$
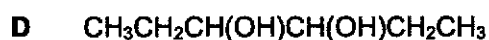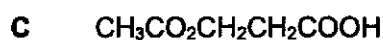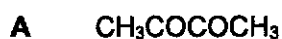
29 Which statements about PVC are correct?

1 PVC produces CO_2 and other poisonous gases during combustion.

2 The rate of biodegradation of PVC in landfill sites is slow.

3 PVC can be used in raincoats due to its water–resistant properties.

A	1, 2 and 3	B	1 and 3 only
C	2 and 3 only	D	1 and 2 only
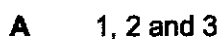
30 A section of a polymer chain is shown.
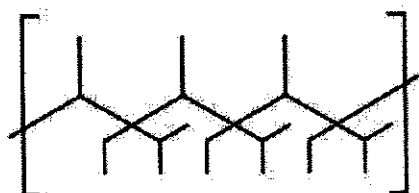
What is the correct monomer?

A

B

C

D

Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination 2020
Year 6

H1 CHEMISTRY

8873/02

Paper 2 Structured Questions

14 September 2020

2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your index number and name 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** the questions.

Section B

Answer **one** question.

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

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use								
P1	P2 Section A					P2 Section B		Total	%
	Q1	Q2	Q3	Q4	Q5	Q6	Q7		
30	15	13	8	14	10	20	20	110	

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[Turn over

Section A

Answer **all** the questions from this section, in the spaces provided.

1 (a) Kevlar® is a synthetic fibre used to make heavy–duty work gloves for workers in the construction industries.

(i) Draw, in the boxes below, the structural formulae of monomers **A** and **B** used to synthesise Kevlar®.
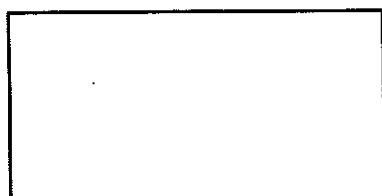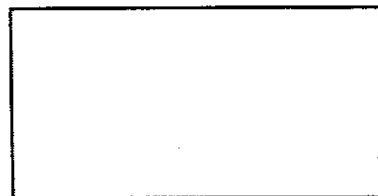
monomer **A**	monomer **B**
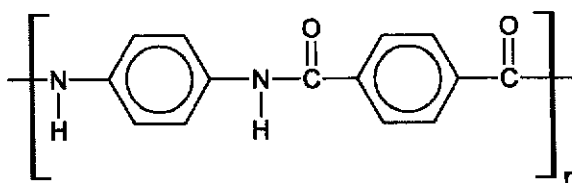
Kevlar®

[2]

(ii) State the type of polymerisation involved.

type of polymerisation... [1]

(iii) Gloves made from Kevlar® cause discomfort to the user as it tends to absorb moisture.

Explain why Kevlar® tends to absorb water. You should include a diagram to support your answer.

....

....

.... [2]

(iv) Gloves made from Kevlar® are durable as they are resistant to many chemicals and solvents, with the exception of strong acids and bases.

Explain what happens when Kevlar® comes into contact with strong acids or bases.

....

....[1]

(b) Chemists have recently found a way of making Kevlar® to be antibacterial. This is achieved by coating it with another polymer, a section of which is shown in Fig. 1.1.
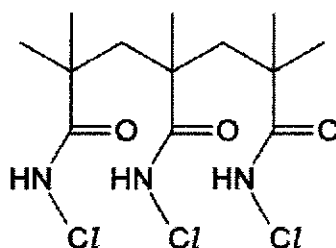
Fig. 1.1

(I) Draw **one** repeat unit of the polymer shown in Fig. 1.1.

[1]

(II) Draw the structure of the monomer from which the polymer in Fig. 1.1 could be made.

State the type of polymerisation involved.

type of polymerisation...
[2]

(c) Nylon is a synthetic polyamide with a structure similar to Kevlar®. It melts on strong heating and has significant commercial applications in fabric, in molded parts for cars and in films for food packaging.

(i) Based on the information provided, suggest the class of polymer which nylon belongs to and use its structure to explain its properties.

class of polymer..

explanation of properties...

....

....[2]

(ii) Sketch the structure of nylon using ∿∿∿ as a simplified representation of the polymer chain. Include labels on your sketch.

[2]

(iii) Predict whether nylon can be recycled. Explain your answer.

....

....

....

....

....[2]

[Total: 15]

2 (a) (i) Define the term *standard enthalpy change of combustion*, $\Delta H_c^{\ominus}$, using liquid ethanol, CH_3CH_2OH, as an example.

Illustrate your answer with a balanced equation, including state symbols.

....

....

....[2]

(ii) When 0.980 g of ethanol was combusted using a spirit burner, the combustion of ethanol raised the temperature of 100 cm³ of water from 21.0 °C to 58.6 °C.

The transfer of the heat evolved in the reaction to the water was only 65% efficient.

Calculate the enthalpy change of combustion of ethanol.

[3]

(iii) The literature value for the standard enthalpy change of combustion of ethanol is −1370 kJ mol⁻¹.

Suggest why the value calculated in (a)(ii) is less exothermic than the literature value despite having taken into account the efficiency of the heat transfer to the water.

....

....[1]

(b) When ethanol reacts with ethanoic acid, in the presence of concentrated sulfuric acid, to form ethyl ethanoate and water, the following equilibrium is established.

$$CH_3CH_2OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$$

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

[1]

(ii) Equimolar amount of ethanol and ethanoic acid were mixed. 1.00 mol of ethyl ethanoate is present at equilibrium.

Given that the value of K_c is 4.0, calculate the initial amount, in moles, of ethanol.

[2]

(c) Ethanol reacts with Group 1 metals in the following reaction.

$$CH_3CH_2OH(aq) + M(s) \rightarrow CH_3CH_2O^-M^+(aq) + \tfrac{1}{2}H_2(g), \text{ where } M = Li, Na, K, Rb, Cs$$

Suggest an explanation, in terms of atomic structure, how you would expect the reactivity of Group 1 metals with ethanol to change down the group.

....

....

....

....

....

....[3]

(d) At low temperatures and pressures, the Group 1 metals can exist as gaseous diatomic molecules. Spectroscopic techniques can be used to measure the bond energies of these diatomic molecules. When measured in this way, the values of the bond energies are given in wavenumbers, which has the unit cm^{-1}.

Some values are shown in Table 2.1.

Table 2.1

diatomic molecule	bond energy / cm^{-1}
K_2	4405
Rb_2	3966
KRb	4180

Calculate the enthalpy change, in cm^{-1}, for the reaction between K_2 and Rb_2.

$$K_2(g) + Rb_2(g) \rightarrow 2KRb(g)$$
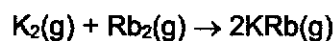
[1]

[Total: 13]

3 When light passes through solutions of chemical compounds, some of the light may be absorbed. The quantity of light absorbed is called the absorbance and it is measured by a spectrophotometer. A simplified diagram of a spectrophotometer is shown in Fig. 3.1.
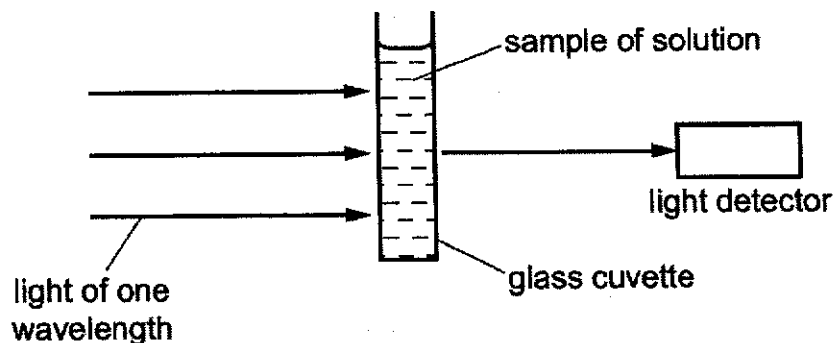
Fig. 3.1

(a) Light passes through two transparent sides of the cuvette. These two sides must be wiped with a cloth to ensure they are clean and dry.

Explain why this procedure makes the readings more accurate.

....

....[1]

Manganese is added to steel to increase its strength. A spectrophotometer can be used to analyse the manganese content in steel. This is done by comparing the absorbance of a solution of $MnO_4^-(aq)$ prepared from a sample of steel, with the absorbance of solutions of known concentrations of $MnO_4^-(aq)$.

(b) A chemist measured the absorbance of solutions of known concentrations of $MnO_4^-(aq)$. The results are shown in Fig. 3.2.

Fig. 3.2

(I) State the relationship between absorbance and concentration of $MnO_4^-(aq)$.

....[1]

(ii) The solutions of known concentrations of $MnO_4^-(aq)$ were prepared using a $MnO_4^-(aq)$ stock solution of concentration 3.00×10^{-4} mol dm^{-3}.

Calculate the volume of $MnO_4^-(aq)$ stock solution required to prepare 25.00 cm^3 of 2.70×10^{-4} mol dm^{-3} $MnO_4^-(aq)$ diluted solution.

[1]

(c) The chemist used a 1.209 g sample of steel for the analysis.

The sample was dissolved in excess acid. An oxidising agent was then added to the solution to oxidise the manganese to MnO_4^- ions. The resulting solution was transferred into a 100 cm³ graduated flask. Deionised water was added so that the total volume of the solution was 100 cm³. This is solution **X**.

(i) A 2 cm³ sample of solution **X** was placed into a clean and dry cuvette and its absorbance measured using the spectrophotometer.

The absorbance of solution **X** was 0.630.

Use Fig. 3.2 to determine the concentration of MnO_4^- ions in solution **X**.

[1]

(ii) Calculate the number of moles of MnO_4^- ions present in 100 cm³ of solution **X**.

[1]

(iii) Calculate the percentage by mass of manganese in the sample of steel.

[2]

(d) The manganese content in the sample of steel can also be determined using titration. The sample of steel is prepared in the same way as (c). The MnO_4^- ions produced are titrated against a solution of Fe^{2+} ions.

Write an ionic equation for the reaction between MnO_4^- and Fe^{2+} ions.

....[1]

[Total: 8]

4   The reaction between NO and O_2 is studied at constant temperature.

The rate equation is found to be

$$rate = k\,[NO]^2[O_2]$$

Some incomplete kinetics data for the reaction between NO and O_2 is provided in Table 4.1.

Table 4.1

experiment	initial concentration of NO / mol dm^{-3}	initial concentration of O_2 / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
1	0.003	0.003	0.241
2	0.006	0.006	
3	0.006		0.322
4		0.006	4.35

(a)   Using the data from experiment 1, calculate a value for the rate constant, k.

value of k ....[1]

(b)   Deduce the units of k.

units of k ....[1]

(c)   Complete Table 4.1 by filling in the blanks with appropriate values.   [3]

(d)   On the axes provided in Fig. 4.1, sketch a graph to show how the rate constant, k, varies with the concentration of O_2, at constant temperature.

k

[O_2]
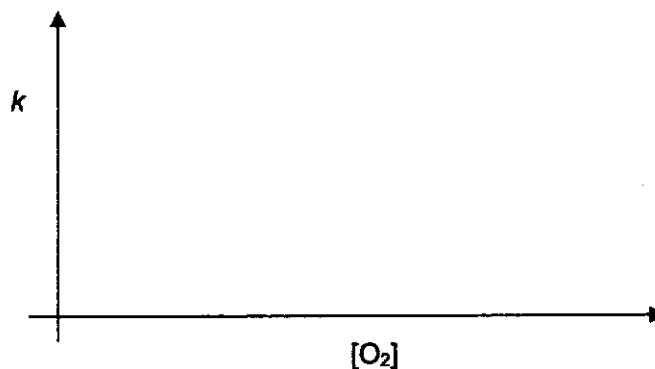
Fig. 4.1

[1]

(e)   State the effect of increasing temperature on the rate constant, k.

....[1]

(f) With the aid of a Boltzmann distribution diagram, explain how increasing the temperature of this gaseous reaction affects its rate of reaction.

....

....

....

....

....[4]

(g) The initial concentrations of O_2 and NO are 0.01 mol dm^{-3} and 0.2 mol dm^{-3} respectively. On the axes provided in Fig. 4.2, sketch a graph to show how the concentration of O_2 varies with time.

By means of construction lines on your graph, show that the order of reaction is first order with respect to O_2.

[O_2] / mol dm^{-3}

time / s
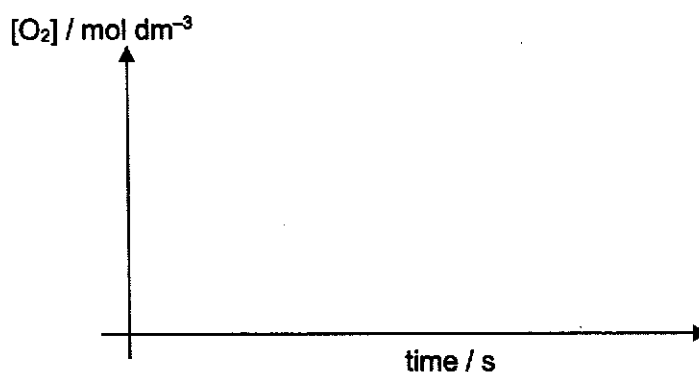
Fig. 4.2

....

....[3]

[Total: 14]

5 (a) A student observed the reactions when sodium chloride and sodium iodide were each reacted separately with concentrated sulfuric acid and with concentrated phosphoric acid. Table 5.1 shows the recorded observations.

Table 5.1

	sodium chloride	sodium iodide
conc. H_2SO_4	colourless acidic gas **A** formed	purple vapour **C** formed
conc. H_3PO_4	colourless acidic gas **A** formed	colourless acidic gas **B** formed

(i) Identify gas **A** and gas **B**.

Gas **A**: .... Gas **B**: ....

[1]

(ii) Describe and explain the relative thermal stabilities of **A** and **B**.

....

...

....

....

....[2]

(iii) From the observations given in Table 5.1, deduce, with reasoning, the relative oxidising strengths of concentrated sulfuric acid and concentrated phosphoric acid.

....

....

....

....[1]

(iv) Explain the oxidising strength of purple vapour **C** relative to other elements above it in the same group of the Periodic Table.

....

....

....

....

....

....[2]

(b) A straight–chain halogenoalkane, **J**, has the molecular formula $C_5H_{11}Cl$. **J** reacts with hot ethanolic NaOH to form only one alkene. This alkene formed is able to exhibit *cis–trans* isomerism.

(i) Describe the criteria necessary for an organic compound to exhibit *cis–trans* isomerism.

....

....

....[1]

(ii) Name and draw the structure of **J**.

Name of **J**: ....
[2]

(iii) Draw and label the structures of the *cis–trans* isomers of the alkene formed from **J**.

[1]

[Total: 10]

15

Section B

Answer **one** question from this section, in the spaces provided.

6 (a) Carbon and silicon are elements in Group 14.

(i) C_{60} and diamond are allotropes of carbon and both exist in different forms, giving rise to different physical properties. For instance, C_{60} sublimes at about 800 K but diamond sublimes only above 3800 K.

Explain why C_{60} and diamond sublime at such different temperatures.

....

....

....

....

....

....[3]

Silicon shows the same kind of structure and bonding as diamond.

(ii) Account for the lower melting point of silicon (1410 °C) as compared to diamond (3350 °C).

....

....

....

....

....[2]

When silicon reacts with magnesium, Mg_2Si forms. Mg_2Si is thought to contain Si^{4-} ion.

(iii) State the full electronic configuration of Si^{4-} ion.

....[1]

(iv) Explain the difference between the atomic radius of Si and the ionic radius of Si^{4-} ion.

....

....

....

....[2]

16

Solid Mg_2Si reacts with dilute hydrochloric acid to form gaseous SiH_4 and a solution of magnesium chloride.

(v) Write an equation, with state symbols, to show the reaction of solid Mg_2Si with dilute hydrochloric acid.

....[1]

(vi) Draw a 'dot–and–cross' diagram for one molecule of SiH_4 and predict its shape.

Shape: .... [2]

(vii) Predict whether or not a molecule of SiH_4 is polar. Explain your answer.

....

....[1]

(viii) SiH_4 gas liquefies at 161 K and solidifies at 88 K.

Outline the importance of intermolecular forces to the liquefaction of gases by relating to two conditions that will result in this process.

....

....

....

....

....

....[2]

(b) Silicon can also form tetrahalosilanes. Table 6.1 shows the boiling points of these compounds.

Table 6.1

	SiF$_4$	SiCl_4	SiBr$_4$	Sil_4
boiling point/ °C	−90.3	56.8	155.0	290.0

Explain the differences in the boiling points seen in Table 6.1.

....

....

....

....

....

....[2]

(c) With the aid of balanced chemical equations, explain why Al_2O_3 behaves as an amphoteric oxide. State symbols are not required.

....

....

....

....

....

....[4]

[Total: 20]

7 The graph shows a sketch of the first ionisation energies of six successive elements in the Periodic Table where their atomic numbers are less than 20 and element **A** is **not** in Period 1.

The letters are **not** the symbols of the elements.

first ionisation
energy / kJ mol^{-1}

A   B   C   D   E   F

element
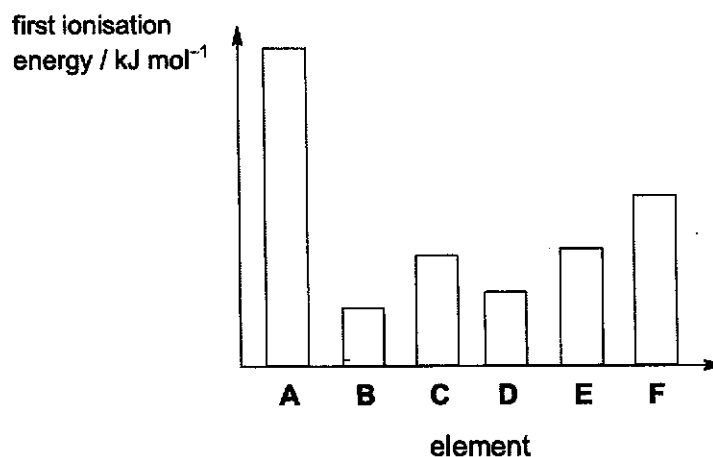
(a)   **(i)**   Explain the term *first ionisation energy*.

....[1]

(ii)   Suggest why the first ionisation energy of **B** is significantly lower than that of **A**.

....

....

....

....

....[2]

(iii)   State the type of orbital in which the second electron is removed from **B**.

type of orbital...[1]

(b)   Calcium lactate is used in some medicines. It forms when lactic acid reacts with calcium carbonate.

$$H_3C \!-\!\! \underset{\underset{COOH}{|}}{\overset{\overset{OH}{|}}{C}} \!-\! H$$

lactic acid

8873/02
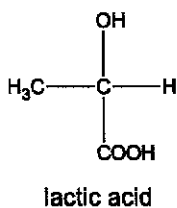
(i)   Write a balanced equation for the reaction between lactic acid and calcium carbonate.

Label the conjugate acid and the conjugate base in your equation.

....

....[2]

Two possible methods of making lactic acid are shown in Fig. 7.1.
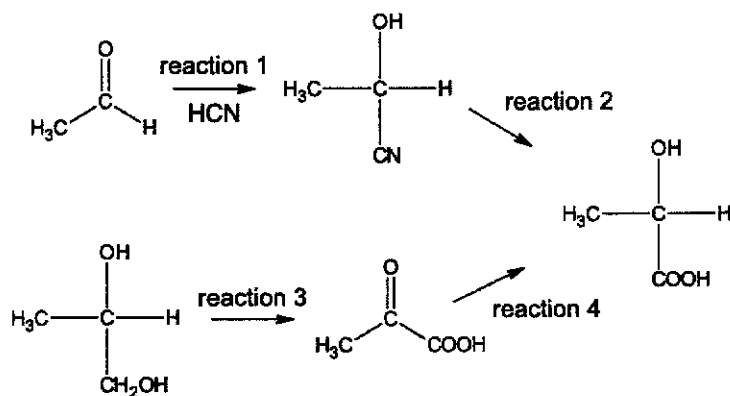
Fig. 7.1

(ii)   Suggest the type of reaction occurring in reaction 1.

type of reaction...[1]

(iii)   State suitable reagents and conditions for reaction 3.

reagents...

conditions...[1]

(iv) $NaBH_4$ is used in reaction 4. Suggest the role of $NaBH_4$.

....[1]

(v)   Dilute hydrochloric acid is used in reaction 2. Explain the differences in behaviour between hydrochloric acid and lactic acid.

....

....

....

....

....[2]

(vi) The acid dissociation constant, K_a, for lactic acid is 1.38×10^{-4} mol dm⁻³. Calculate the pH of a 0.100 mol dm⁻³ solution of lactic acid, given that $[H^+] = \sqrt{K_a \times [\text{lactic acid}]}$.

[2]

(vii) Lactic acid builds up in the bloodstream during intense exercise. Identify and explain how the buffering system in human body helps to control pH in bloodstream.

....

....

....

....

....

....[3]

(c) Lactic acid can react with ethylamine under suitable conditions to produce an amide.

(i) Using relevant bond energy values from the *Data Booklet*, calculate the enthalpy change when one mole of amide bonds is formed in this reaction.

[2]

(ii) Draw the energy profile diagram for this reaction with clear labelling of the activation energy and enthalpy change. Assume that the reaction only involves one step.

[2]

[Total: 20]

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Dunman High School
2020 Preliminary Examinations
H1 Chemistry 8873 Paper 1
Suggested Solutions

Answer Key

B	C	B	D	A		D	A	A	D	D
B	A	D	C	D		B	D	B	A	C
B	D	C	A	B		C	C	C	A	A

1	B
	No of moles of CaO = $\frac{27.0}{40.1+16}$ = 0.481 mol No of moles of Ca^{2+} in 65.0 g of bone = 0.481 mol Mass of Ca = 0.481 x 40.1 = 19.3 g Percentage by mass of Ca in bone = $\frac{19.3}{65.0}$ × 100 = 29.7%
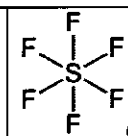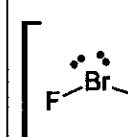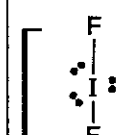
2	C	
✗	A	n (Cl^-) = $\frac{20}{1000}$ × 0.50 = 0.01 mol
✗	B	n (Cl^-) = $\frac{70}{1000}$ × 0.30 = 0.021 mol
✓	C	n (Cl^-) = $\frac{60}{1000}$ × 0.20 × 2 = 0.024 mol
✗	D	$CH_2ClCOOH$ does not dissociate to give Cl^- ions.

3	B
	[R]: $2F_2 + 4e^- \rightarrow 4F^-$ Reacting ratio between F_2 and BrO_x^- is 2:1. ⇒ 1 mole of BrO_x^- loses 4 moles of electron to produce BrO_4^-. Oxidation state of Br in BrO_4^- = +7 ⇒ Oxidation state of Br in BrO_x^- = +3 $(+3) + (-2)(x) = -1$ ∴ $x = 2$

4	D	
✓	A	Cl_2 reduces to Cl^- (O.S. decreases from 0 to −1) Cl_2 oxidises to ClO_3^- (O.S. increases from 0 to +5)
✓	B	C in $H_2C_2O_4$ reduces to CO (O.S. decreases from +3 to +2) C in $H_2C_2O_4$ oxidises to CO_2 (O.S. increases from +3 to +4)
✓	C	N in NO_2 reduces to HNO_2 (O.S. decreases from +4 to +3) N in NO_2 oxidises to HNO_3 (O.S. increases from +4 to +5)
✗	D	S in $FeSO_4$ reduces to SO_2 (O.S. decreases from +6 to +4) O.S. of S in $FeSO_4$ and O.S. of S in SO_3 are the same at +6.

5	A	
✓	1	Angle of deflection is proportional to $\frac{q}{m}$ Since charge on Br^- is the same as Se^- mass of Br^- > Se^- angle of deflection of Br^- < Se^-
✓	2	Number of protons is unchanged when electrons are electrons are increasingly removed from Se ⇒ **nuclear charge unchanged** As electrons are removed, the **increasingly positive charged ion** holds the remaining valence electrons **more strongly** hence **more energy** is required to remove the remaining valence electrons resulting in higher I.E Hence, 2nd I.E. of Se is higher than 1st I.E. of Se.
✓	3	Se to Br is found across period 4. Number of protons/nuclear charge of Br > Se Number of electrons in Br^- = Se^{2-} ⇒ screening effect is similar. Hence, **effective nuclear charge** of Br^- > Se^{2-}. **Electrostatic forces of attraction** between nucleus and valence electrons in Br^- > Se^{2-} Valence electrons in Br^- are **pulled closer** to the nucleus. Thus, the ionic radius of Br^- < Se^{2-}

6	D	
✗	A	No. of protons in both ions are the same, 24.
✗	B	Electronic configuration of $^{52}Cr^+$: $[Ar]$ $3d^54s^1$ Electronic configuration of $^{52}Cr^+$: $[Ar]$ $3d^5$
✗	C	No of neutrons for $^{52}Cr^+$ = 52 − 24 = 28 No of neutrons for $^{53}Cr^{3+}$ = 53 − 24 = 29
✓	D	Electronic configuration of $^{52}Cr^{2+}$: $[Ar]$ $3d^4$ (4 unpaired electrons in d orbital) Electronic configuration of $^{53}Cr^{3+}$: $[Ar]$ $3d^3$ (3 unpaired electrons in d orbital)

7	A	
	A	octahedral 90°
	B	bent 104.5°
	C	linear 180°
	D	O=C=O linear 180°

8	A	
		Boiling points involve the breaking of the intermolecular forces of attractions.
✓	A	Carbon monoxide is a polar molecule hence its pd–pd interactions are stronger than that of nitrogen molecule (id–id).
✗	B	The breaking of σ and π bonds does not affect the boiling points.
✗	C	If the nitrogen molecule has greater surface area for distortion of electron cloud then it would result in a stronger intermolecular forces of attractions (id–id) which leads to a higher boiling point.
✗	D	Both N_2 and CO has the same number of electrons.

9	D	
✗	A	Both alcohols form hydrogen bonds. The boiling point increases with increasing length of alkyl chain. More energy is required to break the stronger id–id interactions between molecules due to the increase in size of electron cloud.
✗	B	The thermal stability of hydrogen halides is related to the H–X bond strength.
✗	C	There isn't any hydrogen bond formed between propanone and propanal.
✓	D	The alcohol has a higher boiling point than aldehyde because of its ability to form hydrogen bonds between the molecules. Aldehyde could not form intermolecular hydrogen bonds.

10	D	
✗	A	MgO partially dissolves in water to give solution of pH 9–10 $MgCl_2$ dissolves in water with slight hydrolysis to form solution of pH 6.5.
✗	B	Al_2O_3 is insoluble in water hence the solution would be pH 7 $AlCl_3$ dissolves in water with appreciable hydrolysis to form solution of pH 3.
✗	C	SiO_2 is insoluble in water hence the solution would be pH 7 $SiCl_4$ hydrolyses to form solution of pH 1–2.
✓	D	P_4O_{10} reacts with water to form solution of pH 2. PCl_5 hydrolyses to form solution of pH 1–2.

11	B
	Beryllium shares a diagonal relationship with aluminium as they exhibit similar properties to each other, one of which is similar electronegativity.

12	A
	The electronegativities decrease down the group. Smallest dipole moment arises from the smallest differences in electronegativity values.

13	D	
		Students need to recall 'bond energy' method and apply Hess' Law
✗	1	First ionisation energy has no bearings on enthalpy change of formation.
✗	2	Activation energy only informs about the kinetics of a reaction but not the enthalpy change of formation.
✓	3	This statement should be inferred as HI having less bond energy than HCl which helps to account for the difference. By Hess' Law, $\Delta H_{rxn}^{\theta} = \Sigma BE$(bonds broken in reactants) $-$ ΣBE(bonds broken in products) $= [BE(H_2) + BE(X_2)] - [2BE(HX)]$

14	C	
✗	A	Since bromine is a liquid and iodine is a solid at room temperature, astatine is expected to be a solid.
✗	B	Electronegativity decrease down Group 17.
✓	C	The bond energy of C–X bond decreases down Group 17. Hence, a weaker C–At bond is expected.
✗	D	The oxidising power of halogen decreases down Group 17.

15	D	
✗	A	From the diagram, both step 1 and 2 are exothermic reactions. Enthalpy change of reaction for the step 1 $(\Delta H_{step\ 1}) = -(111 - 50) = -61$ kJ mol^{-1} Enthalpy change of reaction for the step 2 $(\Delta H_{step\ 2}) = -(138 - 111) = -27$ kJ mol^{-1} (less exothermic than step 1)
✗	B	As step 1 is a reversible reaction, the forward and backward reaction has the same numerical value for enthalpy change but their signs are different.
✗	C	The activation energy for the backward reaction in step 1 is 111 kJ mol^{-1} whereas the forward reaction has activation energy of 50 kJ mol^{-1}.
✓	D	Enthalpy change of reaction for conversion of J to L = Sum of enthalpy change of reaction for first step and second step $= -61 - 27 = -88$ kJ mol^{-1}

16	B	
✗	A	Carbon exists as a solid at 298K.
✓	B	Standard enthalpy change of lattice energy of NaC*l* is the energy evolved when one mole of solid NaC*l* is formed from its gaseous ions.
✗	C	Standard enthalpy change of formation, hydrogen should exists as H_2 gas at 298K.
✗	D	Standard enthalpy change of combustion of CH_4, H_2O exists as liquid water at 298K.

17	D

Let the process efficiency be x %.

$\Delta H_c^{\ominus} = -Q / n (x)$

$-1367 \times 1000 = -\dfrac{mc\Delta T}{\left(\frac{0.86}{46.0}\right)\left(\frac{x}{100}\right)}$

$\Rightarrow -1367 \times 1000 = -\dfrac{(300)(4.18)(18)}{\left(\frac{0.86}{46.0}\right)\left(\frac{x}{100}\right)}$

$\therefore x = 88.3\% \approx 88\%$

18	B

From the graph, we can deduce that the order of reaction with respect to R is <u>0</u> as the graph of $[R]$ against time is a straight line and rate is constant even though $[R]$ is decreasing. Also, when $[S]$ doubled, |gradient| of the graph quadrupled. Thus, the order of reaction with respect to S is <u>2</u>.

✓	1	Statement 1 is **correct** since the order of reaction with respect to R is zero.
✓	2	Statement 2 is **correct** since the order of reaction with respect to S is two.
✗	3	Statement 3 is **inconclusive** since we do not know the order of reaction with respect to T.

19	A	
✓	A	Activation energy, E_a is the minimum amount of energy that effective molecular collisions must possess in order for a chemical reaction to occur. The activation energy of a chemical reaction is closely related to its rate. The higher the activation energy, the slower the chemical reaction will be.
✗	B	Refer to option A.
✗	C	A very small equilibrium constant means that the chemical reaction will favor the reactants. It tells us that at equilibrium, the proportion of reactants is larger than that of the products but it does not tell us whether how fast or slow the reaction rate is.
✗	D	Even if the rate of the reverse reaction may be greater than that of the forward reaction but that still does not help explain why the rate of the forward reaction is slow.

20	C

Let the initial quantity of N be a and the initial quantity of M will be $4a$
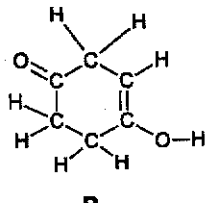
21	B	
✗	A	The presence of a catalyst will speed up BOTH forward and backward reaction to the same extent.
✓	B	At higher temperature, more C_5H_6 is formed indicating that position of equilibrium shifts to the right to absorb excess heat energy. Hence, the forward reaction is endothermic.
✗	C	Pressure on the equilibrium system is increased when compression occurs. By Le Chateliers' Principle, the position of the equilibrium will shift backward to decrease the pressure. Hence less hydrogen iodide will be produced.
✗	D	The value of K_c is a constant when temperature is maintained constant.

22	D

$K_c = \dfrac{[H_2]^4}{[H_2O]^4}$

Units of $K_c = \dfrac{(mol\,dm^{-3})^4}{(mol\,dm^{-3})^4} = $ dimensionless

23	C

$[H^+]$ at 100 °C $= \sqrt{5.50 \times 10^{-13}} = 7.42 \times 10^{-7} \Rightarrow$ pH $= -\log_{10} 7.42 \times 10^{-7} = 6.13$
pH at 25 °C is 7.

✓	1	It can be deduced that extent of dissociation is greater at 100 ºC and therefore $[H^+]$ is also greater resulting in lower pH value.
✗	2	Water is still a BrØnsted–Lowry Base at 100 °C when a strong acid is introduced due to the availability of lone pair of electrons on oxygen atom.
✓	3	The colour of Bromothymol Blue at pH = 7 is green. It should turn blue beyond pH = 7.6

24	A	
		Recall: Arrhenius acid is a substance which releases H^+ in aqueous solution while an Arrhenius base is a substance which releases OH^- in aqueous solution.
✓	A	Both CH_3COOH and $Ca(OH)_2$ are in aqueous phase and CH_3COOH releases H^+ while $Ca(OH)_2$ releases OH^-
✗	B	CO_2 is not an Arrhenius base as it doesn't release OH^-.
✗	C	Na_2O is not an Arrhenius base as it is not in aqueous phase.
✗	D	NH_3 is not an Arrhenius base as it is not in aqueous phase and doesn't release OH^-.
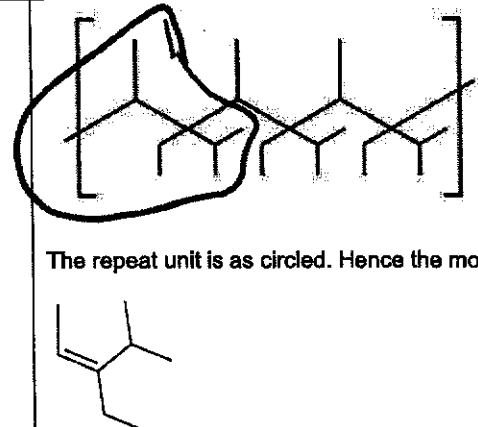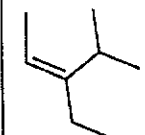
25	B

$$C_2H_5Br \xrightarrow{\text{hot NaOH (aq)}} C_2H_5OH \xrightarrow[\text{H}_2\text{SO}_4]{\text{hot conc}} C_2H_4$$

Step R : substitution reaction

Step S : elimination reaction

26	C

P

27	C
	Both ketone and carboxylic acid can be reduced by lithium aluminium hydride.

28	C	
✗	A	 A does not undergo hydrolysis
✗	B	 Products: CH_3CH_2OH
✓	C	 Products: $HOCH_2CH_2COOH$ Empirical formula: CH_2O
✗	D	$CH_3CH_2CH(OH)CH(OH)CH_2CH_3$ does not undergo hydrolysis.

29	A	
✓	1	PVC combusts to produce CO_2 and other poisonous gases
✓	2	The rate of biodegration of PVC in landfill sites is slow.
✓	3	It lacks alcohol groups to form hydrogen bonding with water molecules and hence. It is water-resistant.

30	A

The repeat unit is as circled. Hence the monomer is:

Name:	Suggested Solutions	Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination 2020
Year 6

H1 CHEMISTRY

8873/02

Paper 2 Structured Questions

14 September 2020
2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your index number and name 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** the questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use									
P1	P2 Section A					P2 Section B		Total	%
	Q1	Q2	Q3	Q4	Q5	Q6	Q7		
30	15	13	8	14	10	20	20	110	

[Turn over

2

Section A

Answer all the questions from this section, in the spaces provided.

1 (a) Kevlar® is a synthetic fibre used to make heavy-duty work gloves for workers in the construction industries.

(i) Draw, in the boxes below, the structural formulae of monomers A and B used to synthesise Kevlar®.

[structural diagram: monomer A (H₂N—C₆H₄—NH₂), arrow to Kevlar®, monomer B (HOOC—C₆H₄—COOH)]

monomer A

Kevlar®

monomer B

(ii) State the type of polymerisation involved.

condensation polymerisation [1]

(iii) Gloves made from Kevlar® cause discomfort to the user as it tends to absorb moisture.

Explain why Kevlar® tends to absorb water. You should include a diagram to support your answer. [2]

[diagram showing hydrogen bonding between Kevlar® and water molecules, labelled "hydrogen bonding"]

3
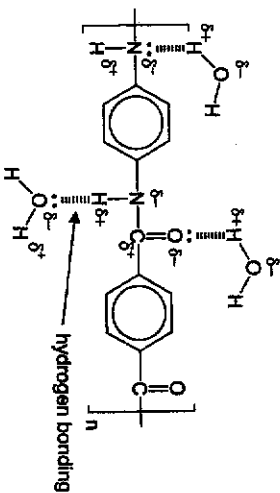
Kevlar® is able to form hydrogen bonding with water molecules and hence absorbs moisture.

[2]

(iv) Gloves made from Kevlar® are durable as they are resistant to many chemicals and solvents, with the exception of strong acids and bases.

Explain what happens when Kevlar® comes into contact with strong acids or bases.

The amide linkages will be hydrolysed by the strong acids or bases hence compromising the strength of the fibre. [1]

(b) Chemists have recently found a way of making Kevlar® to be antibacterial. This is achieved by coating it with another polymer, a section of which is shown in Fig. 1.1.

[structural diagram showing polymer with Cl, HN, O groups]

Fig. 1.1

(i) Draw one repeat unit of the polymer shown in Fig. 1.1.

[structural diagram of repeat unit with CH₃, O, Cl, NH groups, subscript n]

[1]

(ii) Draw the structure of the monomer from which the polymer in Fig. 1.1 could be made.

[structural diagram of monomer with H, C=C, CH₃, O, NH, Cl]
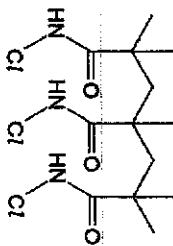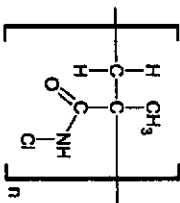
State the type of polymerisation involved.

addition polymerisation [2]

[Turn Over

4

(c) Nylon is a synthetic polyamide with a structure similar to Kevlar®. It melts on strong heating and has significant commercial applications in fabric, in molded parts for cars and in films for food packaging.

(i) Based on the information provided, suggest the class of polymer which nylon belongs and use its structure to explain its properties.

Nylon is a thermoplastic since it can be melted and remoulded easily with no cross–links. It melts on heating, as there are only weak intermolecular forces between polymer chains and the chains slip off from one another.   [2]

(ii) Sketch the structure of nylon using ∿∿∿ as a simplified representation of the polymer chain. Include labels on your sketch.

Weak Intermolecular forces of attraction   [2]
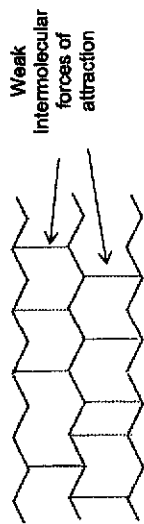
(iii) Predict whether nylon can be recycled. Explain your answer.

Nylon can be recycled because it becomes soft on heating and can be moulded into different shapes for recycling.   [2]

[Total: 15]

5

2 (a) (i) Define the term *standard enthalpy change of combustion*, $\Delta H_c^\ominus$, using liquid ethanol, CH_3CH_2OH, as an example.

Illustrate your answer with a balanced equation, including state symbols.

Standard enthalpy change of combustion ($\Delta H_c^\ominus$) of ethanol is the energy evolved when one mole of ethanol is completely burnt in oxygen under standard conditions.

$$CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$ [2]

(ii) When 0.980 g of ethanol was combusted using a spirit burner, the combustion of ethanol raised the temperature of 100 cm³ of water from 21.0 °C to 58.6 °C.

The transfer of the heat evolved in the reaction to the water was only 65% efficient.

Calculate the enthalpy change of combustion of ethanol.

Heat absorbed by water = $(100)(4.18)(58.6 - 21)$

= 15716.8 J

Heat released from combustion = $\frac{100}{65} \times 15716.8$

= 24180 J

No of moles of ethanol = $\frac{0.980}{46}$

= 0.021304 mol

Enthalpy change of combustion = $-\frac{24180}{0.021304}$

= -1.13×10^6 J mol^{-1} = -1.13×10^3 kJ mol^{-1} [3]

(iii) The literature value for the standard enthalpy change of combustion of ethanol is -1370 kJ mol^{-1}.

Suggest why the value calculated in (a)(ii) is less exothermic than the literature value despite having taken into account the efficiency of the heat transfer to the water.

This is probably because the combustion is not performed under standard conditions.   [1]

(b) When ethanol reacts with ethanoic acid, in the presence of concentrated sulfuric acid, to form ethyl ethanoate and water, the following equilibrium is established.

$$CH_3CH_2OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$$

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

$$K_c = \frac{[CH_3COOCH_2CH_3][H_2O]}{[CH_3CH_2OH][CH_3COOH]}$$

[1]

(ii) Equimolar amount of ethanol and ethanoic acid were mixed. 1.00 mol of ethyl ethanoate is present at equilibrium.

Given that the value of K_c is 4.0, calculate the initial amount, in moles, of ethanol.

Let the initial amount of CH_3CH_2OH be x

$CH_3CH_2OH(l)$	+ $CH_3COOH(l)$	⇌ $CH_3COOCH_2CH_3(l)$	+ $H_2O(l)$
I	x	x	0	0
C	-1	-1	+1	+1
E	x-1	x-1	1	1

Let the volume of the reaction mixture be V dm³

$$4 = \frac{\frac{1}{V} \times \frac{1}{V}}{\frac{x-1}{V} \times \frac{x-1}{V}}$$

$$4 = 1 / (x-1)(x-1)$$

$(x-1)(x-1) = ¼$
$x-1 = ½$
$x = 1.50$ mol

Initial no. of moles of ethanol = 1.50 mol

[2]

(c) Ethanol reacts with Group 1 metals in the following reaction.

$CH_3CH_2OH(aq) + M(s) \rightarrow CH_3CH_2O^-M^+(aq) + \frac{1}{2}H_2(g)$, where M = Li, Na, K, Rb, Cs

Suggest an explanation, in terms of atomic structure, how you would expect the reactivity of Group 1 metals with ethanol to change down the group.

The reactivity of Group 1 metals with ethanol will increase down the group.

Number of filled electron shells increases and valence electrons are increasingly further away from the nucleus

Valence electrons are less strongly attracted to the nucleus and easier to remove the valence electron, hence it is more easily oxidised.

[3]

(d) At low temperatures and pressures, the Group 1 metals can exist as gaseous diatomic molecules. Spectroscopic techniques can be used to measure the bond energies of these diatomic molecules. When measured in this way, the values of the bond energies are given in wavenumbers, which has the unit cm⁻¹.

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Some values are shown in Table 2.1.

Table 2.1

diatomic molecule	bond energy / cm⁻¹
K_2	4405
Rb_2	3966
KRb	4180

Calculate the enthalpy change, in cm⁻¹, for the reaction between K_2 and Rb_2.

$$K_2(g) + Rb_2(g) \rightarrow 2KRb(g)$$

Enthalpy change = $[BE(K_2) + BE(Rb_2)] - 2BE(KRb)$
= $[4405 + 3966] - 2(4180)$
= $+11.0$ cm⁻¹

[1]

[Total: 13]

[Turn Over

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3 When light passes through solutions of chemical compounds, some of the light may be absorbed. The quantity of light absorbed is called the absorbance and it is measured by a spectrophotometer. A simplified diagram of a spectrophotometer is shown in Fig. 3.1.

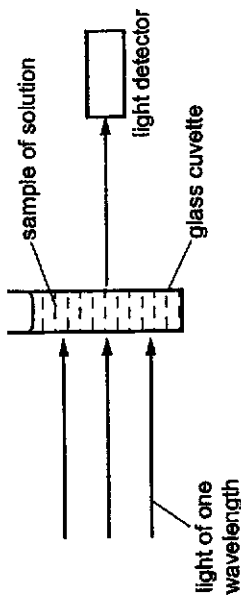light of one wavelength — sample of solution — light detector — glass cuvette

Fig. 3.1

(a) Light passes through two transparent sides of the cuvette. These two sides must be wiped with a cloth to ensure they are clean and dry.

Explain why this procedure makes the readings more accurate.

This procedure removes the water that may be left on the cuvette which may absorb light. [1]

Manganese is added to steel to increase its strength. A spectrophotometer can be used to analyse the manganese content in steel. This is done by comparing the absorbance of a solution of $MnO_4^-(aq)$ prepared from a sample of steel, with the absorbance of solutions of known concentrations of $MnO_4^-(aq)$.

(b) A chemist measured the absorbance of solutions of known concentrations of $MnO_4^-(aq)$. The results are shown in Fig. 3.2.
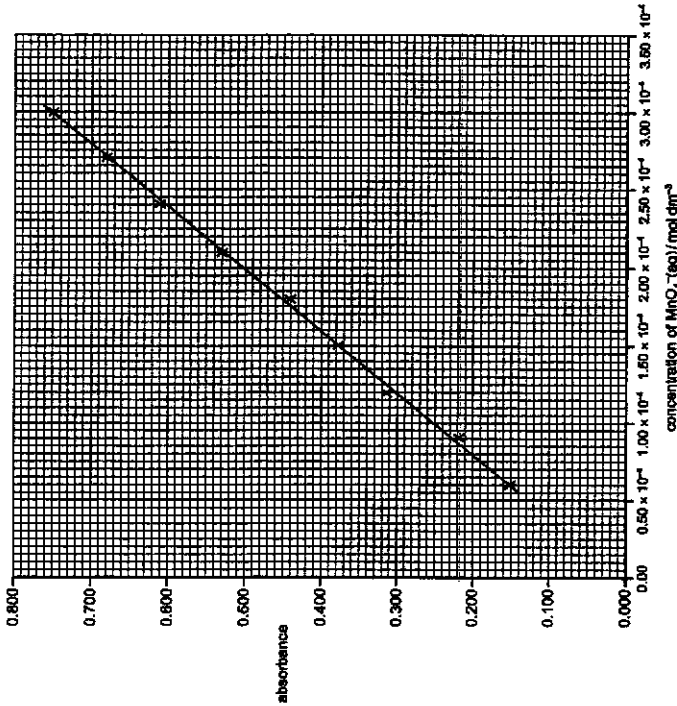
9

Fig. 3.2

(i) State the relationship between absorbance and concentration of $MnO_4^-(aq)$.

The absorbance is directly proportional to the concentration of $MnO_4^-(aq)$. [1]

(ii) The solutions of known concentrations of $MnO_4^-(aq)$ were prepared using a $MnO_4^-(aq)$ stock solution of concentration 3.00×10^{-4} mol dm^{-3}.

Calculate the volume of $MnO_4^-(aq)$ stock solution required to prepare 25.00 cm^3 of 2.70×10^{-4} mol dm^{-3} $MnO_4^-(aq)$ diluted solution.

$C_oV_o = C_dV_d$

$(3.00 \times 10^{-4})(V_o) = (2.70 \times 10^{-4})(25.00)$

$V_o = 22.50$ cm^3 [1]

(c) The chemist used a 1.209 g sample of steel for the analysis.

The sample was dissolved in excess acid. An oxidising agent was then added to the solution to oxidise the manganese to MnO_4^- ions. The resulting solution was transferred into a 100 cm^3 graduated flask. Deionised water was added so that the total volume of the solution was 100 cm^3. This is solution X.

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(i) A 2 cm³ sample of solution X was placed into a clean and dry cuvette and its absorbance measured using the spectrophotometer.

The absorbance of solution X was 0.630.

Use Fig. 3.2 to determine the concentration of MnO_4^- ions in solution X.

Concentration of MnO_4^- ions in solution X = 2.50 x 10⁻⁴ mol dm⁻³

[1]

(ii) Calculate the number of moles of MnO_4^- ions present in 100 cm³ of solution X.

Number of moles of MnO_4^- ions = 2.50 x 10⁻⁴ x $\frac{100}{1000}$

= 2.50 x 10⁻⁵ mol

[1]

(iii) Calculate the percentage by mass of manganese in the sample of steel.

No of moles of Mn present in the sample = 2.50 x 10⁻⁵ mol

Mass of Mn present in the sample = 2.50 x 10⁻⁵ x 54.9

= 0.0013725 g

Percentage by mass = $\frac{0.0013725}{1.209}$ x 100%

= 0.114%

[2]

(d) The manganese content in the sample of steel can also be determined using titration. The sample of steel is prepared in the same way as (c). The MnO_4^- ions produced are titrated against a solution of Fe^{2+} ions.

Write an ionic equation for the reaction between MnO_4^- and Fe^{2+} ions.

$MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$

[1]

[Total: 8]

4. The reaction between NO and O_2 is studied at constant temperature.

The rate equation is found to be

rate = k [NO]²[O₂]

Some incomplete kinetics data for the reaction between NO and O_2 is provided in Table 4.1.

Table 4.1

experiment	Initial concentration of NO / mol dm⁻³	Initial concentration of O₂ / mol dm⁻³	Initial rate / mol dm⁻³ s⁻¹
1	0.003	0.003	0.241
2	0.006	0.006	
3	0.006		0.322
4		0.006	4.35

(a) Using the data from experiment 1, calculate a value for the rate constant k.

rate = k [NO]²[O₂]
From experiment 1,
0.241 = k [0.003]²[0.003]
k = 8.93 x 10⁸

[1]

(b) Deduce the units of k.

mol dm⁻³ s⁻¹ = (units of k) (mol dm⁻³)³
units of k = $\frac{mol\ dm^{-3}s^{-1}}{(mol\ dm^{-3})^3}$
units of k = mol⁻² dm⁶ s⁻¹

[1]

(c) Complete Table 4.1 by filling in the blanks with appropriate values.

[3]

(d) On the axes provided in Fig. 4.1, sketch a graph to show how the rate constant, k, varies with the concentration of O_2, at constant temperature.

experiment	Initial concentration of NO / mol dm⁻³	Initial concentration of O₂ / mol dm⁻³	initial rate / mol dm⁻³ s⁻¹
1	0.003	0.003	0.241
2	0.006	0.006	
3	0.006		0.322
4		0.006	4.35

[1]

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(g) The initial concentrations of O_2 and NO are 0.01 mol dm^{-3} and 0.2 mol dm^{-3} respectively. On the axes provided in Fig. 4.2, sketch a graph to show how the concentration of O_2 varies with time.

By means of construction lines on your graph, show that the order of reaction is first order with respect to O_2.

[O₂] / mol dm⁻³ ... 0.01, 0.005, 0.0025 ... time / s ... 1st t₁/₂, 2nd t₁/₂

Fig. 4.2

Order of reaction w.r.t. O_2 is 1 if the half-life of O_2 is constant, i.e. 1st $t_{1/2}$ = 2nd $t_{1/2}$.

[3]

[Total: 14]

12

Fig. 4.1

k vs [O₂]
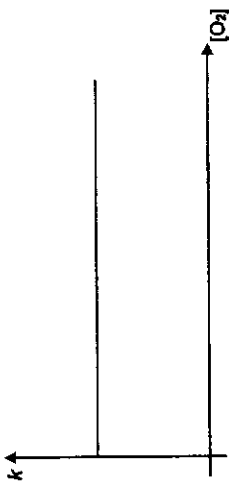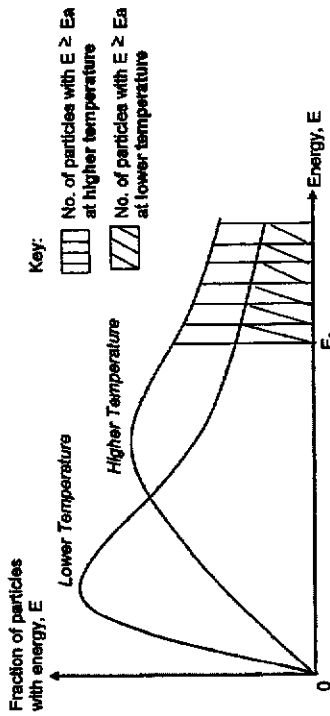
[1]

(e) State the effect of increasing temperature on the rate constant, k.

k increases as temperature increases.

[1]

(f) With the aid of a Boltzmann distribution diagram, explain how increasing the temperature of this gaseous reaction affects its rate of reaction.

Fraction of particles with energy, E — Lower Temperature, Higher Temperature — E_a — Energy, E

Key:
No. of particles with E ≥ E_a at higher temperature
No. of particles with E ≥ E_a at lower temperature

When temperature of the reaction increases,
♦ average kinetic energy of reactant particles increases
♦ there are more reactant particles with energy ≥ E_a, number of effective collisions per unit time / frequency of effective collisions increases
♦ rate of reaction increases, since the rate of reaction is proportional to the frequency of effective collisions

[4]

5 (a) A student observed the reactions when sodium chloride and sodium iodide were each reacted separately with concentrated sulfuric acid and with concentrated phosphoric acid. Table 5.1 shows the recorded observations.

Table 5.1

	sodium chloride	sodium iodide
conc. H_2SO_4	colourless acidic gas A formed	purple vapour C formed
conc. H_3PO_4	colourless acidic gas A formed	colourless acidic gas B formed

(i) Identify gas A and gas B.

Gas A: <u>HCl</u>   Gas B: <u>HI</u>   [1]

(ii) Describe and explain the relative thermal stabilities of A and B.

- The thermal stability of Gas A (HCl) is greater than that of Gas B (HI).
- This is due to the bond energy of H–Cl being greater than that of H–I or covalent bond strength of H–Cl greater than that of H–I   [2]

(iii) From the observations given in Table 5.1, deduce, with reasoning, the relative oxidising strengths of concentrated sulfuric acid and concentrated phosphoric acid.

Oxidising strength of conc. sulfuric acid > conc. phosphoric acid Concentrated sulfuric acid oxidises the iodide ions in NaI to iodine but concentrated phosphoric acid cannot.   [1]

(iv) Explain the oxidising strength of purple vapour C relative to other elements above it in the same group of the Periodic Table.

Down Group 17,
- Number of electronic shells increases and each successive element has its valence electrons located in a shell with a higher / larger principal quantum number, n.
- Hence, valence electrons are increasingly further away from the nucleus and are less strongly attracted to the nucleus.
- ∴ Ease of gaining electrons decreases down the group.
- ∴ Oxidising ability of halogens decreases from $F_2 > Cl_2 > Br_2 > I_2$.   [2]

(b) A straight-chain halogenoalkane, J, has the molecular formula $C_6H_{11}Cl$. J reacts with hot ethanolic NaOH to form only one alkene. This alkene formed is able to exhibit *cis-trans* isomerism.

(i) Describe the criteria necessary for an organic compound to exhibit *cis-trans* isomerism.

There must be restricted rotation due to the presence of π bond in C=C or ring structure.

Two different substituents must be attached to each carbon of the double bond.   [1]

(ii) Name and draw the structure of J.
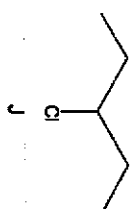
Name of J: 3-chloropentane   [2]

(iii) Draw and label the structures of the *cis-trans* isomers of the alkene formed from J.   [1]
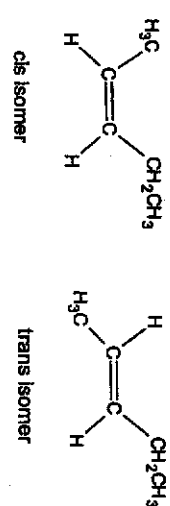
cis isomer   trans isomer

[Total: 10]

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Section B

Answer one question from this section, in the spaces provided.

6 (a) Carbon and silicon are elements in Group 14.

(i) C_{60} and diamond are allotropes of carbon and both exist in different forms, giving rise to different physical properties. For instance, C_{60} sublimes at about 800 K but diamond sublimes only above 3800 K.

Explain why C_{60} and diamond sublime at such different temperatures.

C_{60} exist as simple covalent molecules with weak intermolecular instantaneous dipole-induced dipole interactions but diamond has a giant covalent structure with strong covalent bonds between the carbon atoms.

Hence much more energy is required to break the covalent bonds in diamond. [3]

Silicon shows the same kind of structure and bonding as diamond.

(ii) Account for the lower melting point of silicon (1410 °C) as compared to diamond (3350 °C).

The orbitals used for forming C—C covalent bonds are smaller and less diffuse than those used for forming Si—Si covalent bonds.

There is thus more effective overlap of the orbitals of C and this accounts for the stronger C—C bond, which requires more energy to be broken. Hence, silicon has a lower melting point than diamond. [2]

When silicon reacts with magnesium, Mg_2Si forms. Mg_2Si is thought to contain the Si^{4-} ion.

(iii) State the full electronic configuration of Si^{4-} ion.

$1s^2 2s^2 2p^6 3s^2 3p^6$ [1]

(iv) Explain the difference between the atomic radius of Si and the ionic radius of Si^{4-} ion. [2]

• Electrons are added to the same valence shell to form the anion.
• Greater interelectronic repulsion occurs between the electrons, while nuclear charge remains constant (due to same number of protons in nucleus).
• Weaker electrostatic forces of attraction between nucleus and valence electrons in anion.
• Valence electrons become further away from the nucleus.
• Thus, ionic radius of an anion is larger than its corresponding atomic radius.

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Solid Mg_2Si reacts with dilute hydrochloric acid to form gaseous SiH_4 and a solution of magnesium chloride.

(v) Write an equation, with state symbols, to show the reaction of solid Mg_2Si with dilute hydrochloric acid. [1]

$Mg_2Si(s) + 4HCl(aq) \rightarrow SiH_4(g) + 2MgCl_2(aq)$

(vi) Draw a 'dot-and-cross' diagram for one molecule of SiH_4 and predict its shape. [2]

H
H Si H
H
tetrahedral

(vii) Predict whether or not a molecule of SiH_4 is polar. Explain your answer.

SiH_4 is non-polar as there is no overall net dipole moment /polar bonds arranged symmetrically such that the dipole moments cancel off. [1]

(viii) SiH_4 gas liquefies at 161 K and solidifies at 88 K.

Outline the importance of intermolecular forces to the liquefaction of gases by relating to two conditions that will result in this process.

The liquefaction of gases takes place when the intermolecular forces of attraction become so high/ so significant that they bind the gas particles together to form the liquid state.

At high pressure, the molecules come closer together and thus, the intermolecular forces of attraction becomes more significant.

By lowering the temperature, the kinetic energy of the molecules decreases and with that, the intermolecular forces of attraction becomes more significant. [2]

(b) Silicon can also form tetrahalosilanes. Table 6.1 shows the boiling points of these compounds.

Table 6.1

	SiF_4	$SiCl_4$	$SiBr_4$	SiI_4
boiling point/ °C	−90.3	56.8	155.0	290.0

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Explain the differences in the boiling points seen in Table 6.1.

The boiling point of the tetrahalosilanes increases as we move from F to I.

All four tetrahalosilanes exist as non-polar, simple covalent molecules, with instantaneous dipole-induced dipole interactions found between the molecules.

As the atomic size of the halogen increases from F to I, the size of the electron cloud increases which results in greater momentary polarisation of the electron cloud, and thus, more energy is required to overcome the increasingly stronger instantaneous dipole-induced dipole interactions.

[2]

(c) With the aid of balanced chemical equations, explain why Al_2O_3 behaves as an amphoteric oxide. State symbols are not required.

Al^{3+} is a small and highly charged ion. Its high charge density gives it great polarising power. This results in the polarisation of the O^{2-} ion, giving the ionic bond between Al^{3+} and O^{2-} ions partial covalent character.

Al_2O_3 undergoes neutralisation with both acids and bases to form salt solutions.

$Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$
$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2NaAl(OH)_4(aq)$
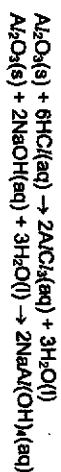
[4]

[Total: 20]

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7 The graph shows a sketch of the first ionisation energies of six successive elements in the Periodic Table where their atomic numbers are less than 20 and element **A** is **not** in Period 1.

The letters are **not** the symbols of the elements.

first ionisation energy / kJ mol⁻¹

A B C D E F — element
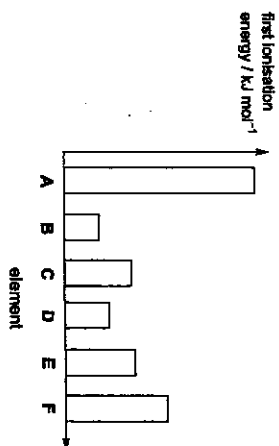
(a) (i) Explain the term *first ionisation energy*.

First ionisation energy is the amount of energy to remove one mole of electrons from one mole of gaseous atoms to form one mole of singly positively charged ions.

[1]

(ii) Suggest why the first ionisation energy of **B** is significantly lower than that of **A**.

The nuclear charge increases from **A** to **F** due to increasing number of protons. However, since the first electron of **B** is removed from a shell of higher principal quantum number, the electron is further away from the nucleus. Hence, lesser energy is required to remove the first electron from **B** than from **A**.

[2]

(iii) State the type of orbital in which the second electron is removed from **B**.

2p orbital

[1]

(b) Calcium lactate is used in some medicines. It forms when lactic acid reacts with calcium carbonate.

H_3C—C—COOH, OH, H

lactic acid

(i) Write a balanced equation for the reaction between lactic acid and calcium carbonate.

Label the conjugate acid and the conjugate base in your equation.

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$$2\ H_3C\text{-}\underset{\underset{COOH}{|}}{\overset{\overset{OH}{|}}{C}}\text{-}H + CaCO_3 \longrightarrow Ca^{2+} + CO_2 + H_2O$$

conjugate acid
conjugate base

Two possible methods of making lactic acid are shown in Fig. 7.1.

reaction 1 HCN

reaction 2

reaction 3

reaction 4

Fig. 7.1

(ii) Suggest the type of reaction occurring in reaction 1. [1]

Addition

(iii) State suitable reagents and conditions for reaction 3. [1]

$KMnO_4$ in dilute sulfuric acid, heat under reflux

(iv) $NaBH_4$ is used in reaction 4. Suggest the role of $NaBH_4$. [1]

Reducing agent

(v) Dilute hydrochloric acid is used in reaction 2. Explain the differences in behaviour between hydrochloric acid and lactic acid. [1]

Hydrochloric acid is a strong acid and completely dissociates in water while lactic acid is a weak acid that undergoes partial dissociation in water. [2]

(vi) The acid dissociation constant, K_a, for lactic acid is 1.38×10^{-4} mol dm^{-3}. Calculate the pH of a 0.100 mol dm^{-3} solution of lactic acid, given that $[H^+] = \sqrt{K_a \times [\text{lactic acid}]}$. [2]

$[H^+] = \sqrt{1.38 \times 10^{-4} \times 0.100}$
$= 3.715 \times 10^{-3}$ mol dm^{-3} (4sf)
pH $= -\log(4.00 \times 10^{-3})$
$= 2.43$ (3 sf)

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(vii) Lactic acid builds up in the bloodstream during intense exercise. Identify and explain how the buffering system in human body helps to control pH in bloodstream. [3]

The buffering system in human body is that of H_2CO_3/HCO_3^-. As lactic acid builds up in bloodstream, HCO_3^- will react with the H$^+$ ion from lactic acid to produce H_2CO_3. This decreases the concentration of H$^+$ ions in bloodstream thereby maintaining a constant pH.

(c) Lactic acid can react with ethylamine under suitable conditions to produce an amide.

[lactic acid] + [ethylamine] $\longrightarrow$ [amide] + H_2O

(i) Using relevant bond energy values from the *Data Booklet*, calculate the enthalpy change when one mole of amide bonds is formed in this reaction. [2]

By Hess' Law,
$\Delta H_{rxn}^{\ominus} = \Sigma BE(\text{bonds broken in reactants}) - \Sigma BE(\text{bonds broken in products})$
$= [360\ (1\ C=O) + 390\ (1\ N\text{-}H)] - [305\ (1\ C\text{-}N) + 460\ (1\ O\text{-}H)]$
$= 750 - 765$
$= -15.0$ kJ mol^{-1} (3 sf)

(ii) Draw the energy profile diagram for this reaction with clear labelling of the activation energy and enthalpy change. Assume that the reaction only involves one step. [2]

energy / kJ mol^{-1}

activation energy

lactic acid + ethylamine

$H = -15$ kJ mol^{-1}

amide + water

reaction pathway

[Total: 20]

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