[Turn Over

Section A

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

1 The periodic table is an arrangement of the chemical elements, organised on the basis of their atomic numbers, electron configurations and chemical properties.

(a) In 1649, Hennig Brand discovered a new element with his experiment on distilled human urine that resulted in the production of a glowing white substance, which he named as phosphorus.

(i) State the electron configuration of phosphorus.

……

(ii) Explain the difference in ionisation energy between phosphorus and sulfur.

……

……

……

[3]

(b) In 1817, Johann Wolfgang Döbereiner began to formulate one of the earliest attempts to classify the elements in the Periodic Table. He found that he could group some of the elements into groups of three. He termed these groups ‘triads’. One of the triads that were classified by him is: calcium, strontium and barium.

(i) Describe the trend in atomic radius from calcium to barium.

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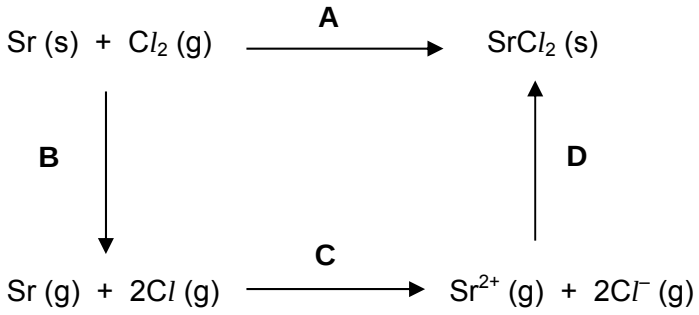
……

1 (b) The energy cycle below shows how strontium chloride is formed from strontium.



(ii) Using the data given below and relevant data from the *Data Booklet*, prove that the enthalpy changes represented by **B** and **C** is +408 kJ mol^{-1} and +910 kJ mol^{-1} respectively.

	$\Delta H^{\ominus}$ / kJ mol^{-1}
Sr (s) → Sr (g)	+164
Cl (g) → Cl^- (g)	-349
Sr (s) + Cl_2 (g) → $SrCl_2$ (s)	-829

1 (b) (iii) Hence, using the energy cycle and the data given above, calculate the lattice energy of $SrCl_2$.

(iv) Explain the difference in lattice energy between $SrCl_2$ and $RbCl$.

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……

……

[9]

[Total:12]

2 (a) A 2.35 g mixture of Na_2O, Al_2O_3 and SiO_2 was analysed to determine the percentage by mass of each oxide present in the mixture. The mixture was first dissolved in water and the solution was filtered. The residue which then contained two of the oxides was then left to stand to evaporate. After some time, the residue was weighed and the mass was found to be 1.93 g. 100 cm^3 of 0.200 mol dm^{-3} hydrochloric acid was added to the residue. The excess acid required 5.20 cm^3 of 0.0500 mol dm^{-3} sodium hydroxide for neutralisation.

(i) Identify the oxide(s) present in the residue and filtrate.

	Oxide(s)
Residue	
Filtrate	

(ii) Identify the oxide that reacts with hydrochloric acid and hence write the balanced equation for this reaction.

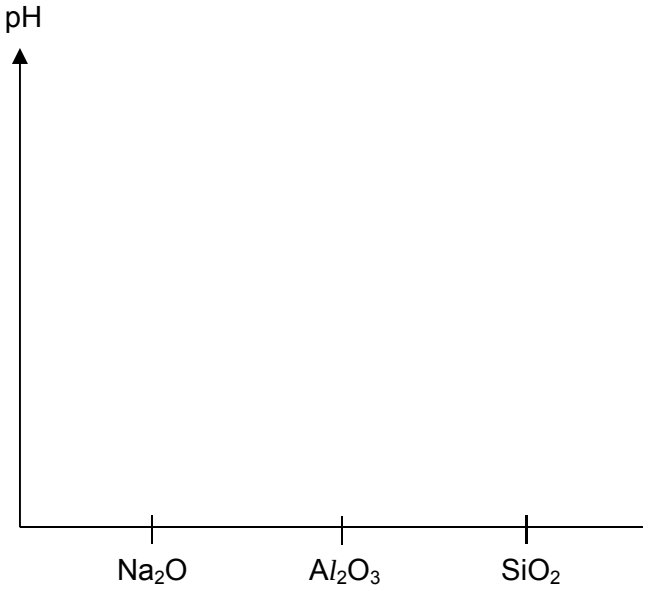
……

……

(iii) Calculate the percentage by mass of the three oxides present in the mixture.

[8]

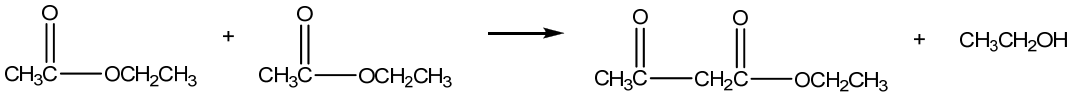
2 (b) Using the axes given below, sketch the graph for the pH of Na_2O, Al_2O_3 and SiO_2 when they are dissolved in water.



[2]

[Total: 10]

3 **(a)** The following reaction is a carbon-carbon bond forming process that is named after the chemist, Rainer Ludwig Claisen.

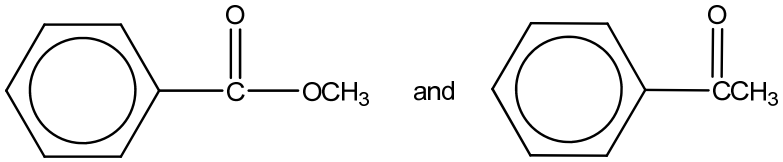


Compound **D** Compound **D** Compound **E** Compound **F**

(i) State the type of reaction.

……

(ii) Hence, suggest the products formed between the following two compounds.



Compound **G** Compound **H**

(iii) Compound **D** can be produced in the laboratory via an esterification reaction. Name the two reactants and state the reagent and condition for this reaction.

……

……

(iv) Name the functional groups that are present in compound **E**.

……

3 (a) (v) Explain how the acidity of compound **F** differs from that of butanoic acid.

……

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……

……

(vi) State a simple chemical test that will react with both compounds **E** and **F**, and state the observation.

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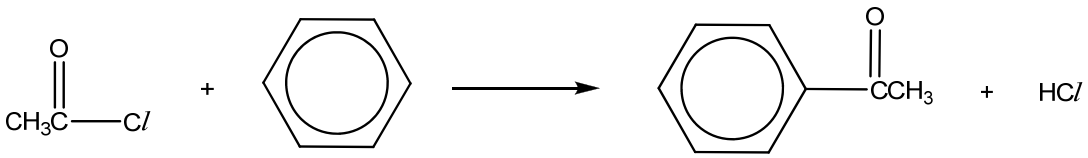
……

[10]

(b) Compound **H** is formed from the following reaction. This reaction uses the same condition as when chlorine reacts with benzene



Compound **H**

(i) State the type of reaction.

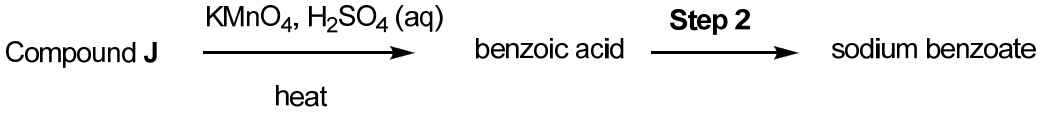
……

(ii) State the condition used for the above reaction.

……

3 (b) Benzene in soft drinks is of potential concern due to the carcinogenic nature of the benzene molecule which is formed from benzoic acid. Benzoic acid is often added to drinks as a preservative in the form of its salt, sodium benzoate.

The following reaction scheme shows how sodium benzoate is formed from Compound **J**.

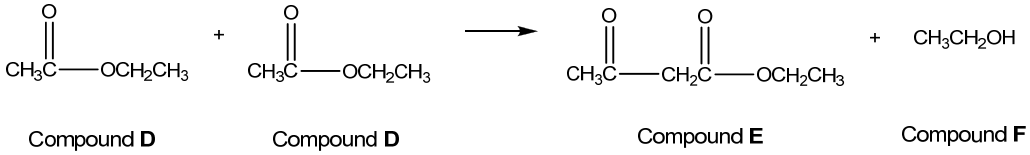


(iii) Draw the structure of Compound **J**.

(iv) Write the balanced equation for **Step 2**.

[4]

3 (c) (i) Given the data below, calculate the standard enthalpy change of reaction of the following reaction from **(a)**.



Compound **D** Compound **D** Compound **E** Compound **F**

Compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
D	−480	***x***
E	−640	−3150
F	−277	−1371

(ii) Hence, calculate the value of ***x***.

[4]

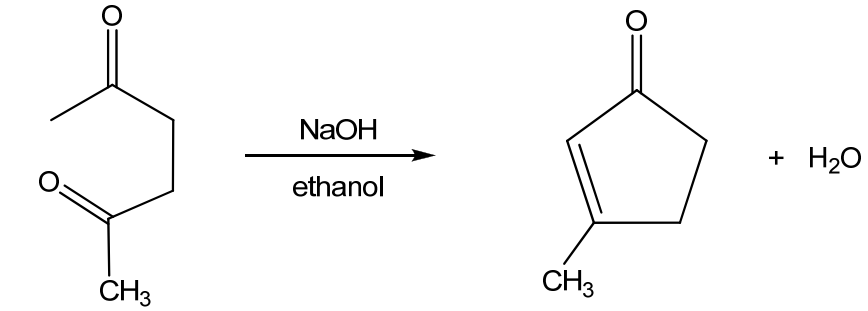
[Total: 18]

Section B

Answer **two** questions from this section on separate answer paper.

4 When a dicarbonyl compound is reacted with a base, an intramolecular aldol reaction can occur. This reaction is very useful in the synthesis of cyclic compounds.

Hexane-2,5-dione undergoes intramolecular aldol reaction to form 3-methylcyclopent-2-enone when treated with ethanolic sodium hydroxide.

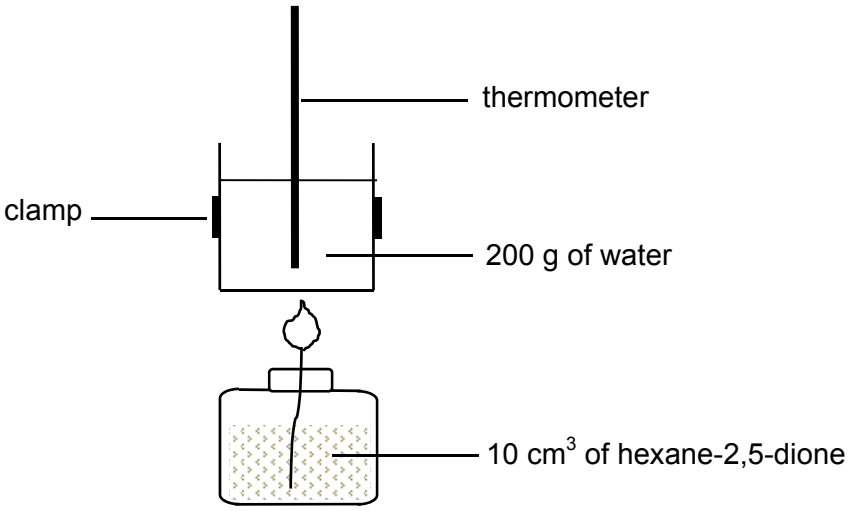


hexane-2,5-dione 3-methylcyclopent-2-enone

(a) Using relevant bond energies from the *Data Booklet,* determine a value for the enthalpy change for this reaction.

[2]

(b) Hexane-2,5-dione was burned in a spirit burner under a beaker of water, as shown in the diagram below.



The temperature results obtained are shown below.

Original temperature of water = 27.0°C

Final temperature of water = 28.5°C

The density of hexane-2,5-dione is 0.973 g cm^{-3} and its molecular mass is 114.

The specific heat capacity of water is 4.18 J g^{-1} K^{-1}.

4 (b) (i) Explain what is meant by the *standard enthalpy change of combustion*.

(ii) Write an equation which represents the standard enthalpy change of combustion of hexane-2,5-dione.

(iii) Calculate the standard enthalpy change of combustion of hexane-2,5-dione in kJ mol^{-1} given that all the hexane-2,5-dione in the spirit burner was used in the combustion.

(iv) The actual value of the standard enthalpy change of combustion of hexane-2,5-dione is -20.5 kJ mol^{-1}.

Compare this value to the one you have calculated in **(iii)** and suggest a reason for the discrepancy.

[6]

(c) A student wants to investigate if aqueous sodium hydroxide can be used for the intramolecular aldol reaction. While searching for the aqueous sodium hydroxide reagent, the student realised that three solutions of NaOH, NaC*l* and A*l*Cl_3 were mislabelled.

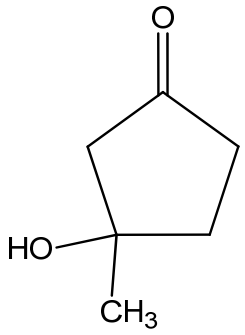
The student measured the pH of the three solutions of equal concentration and obtained the following results.

Solution	pH
X	3
Y	7
Z	11

(i) With the aid of relevant equations, suggest the identities of solutions **X**, **Y** and **Z**.

4 (c) (ii) The student realised that when aqueous sodium hydroxide was used for the aldol reaction, the rate of reaction was considerably decreased.

One of the reasons he proposed was the intermediate of the reaction, as shown below, is highly soluble in water. Hence, the activation energy for the formation of the final product increases.



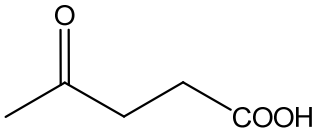
intermediate

With the aid of a diagram, explain the high solubility of the intermediate in water.

[6]

(d) Compound **E**, $C_6H_{12}O$, has the following properties:

- Decolourises aqueous bromine.
- Forms yellow precipitate with alkaline aqueous iodine.
- Reacts with acidified potassium manganate (VII) to form compound **G** and carbon dioxide.



compound **G**

(i) Use this information to deduce the structural formula for **E**, explaining your reasons.

(ii) **G** can be synthesised from 4-chlorobutan-2-one by the following series of reactions.

$$CH_3COCH_2CH_2Cl \xrightarrow{I} \mathbf{F} \xrightarrow{II} \mathbf{G}$$

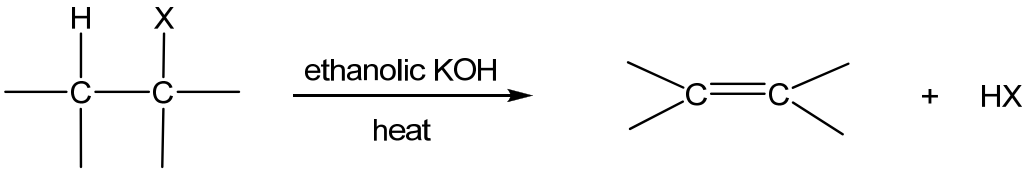
Draw the structure of the intermediate product **F**.

Suggest the reagents and conditions for reactions I and II.

[6]

[Total: 20]

5 Halogenoalkanes reacts with hot ethanolic potassium hydroxide to produce alkenes.



(a) **(i)** State the name of the type of reaction.

(ii) When silver nitrate solution was added to the resulting reaction mixture, a precipitate was formed.

Suggest the colour of the precipitates formed when silver nitrate solution is added to separate reaction mixtures of chloroethane, bromoethane and iodoethane.

Write relevant balanced equations using bromoethane as your example.

(iii) Explain the difference in reactivities of these halogenoethanes.

[5]

(b) The rate of reaction between chloroethane and ethanolic KOH was followed by measuring the concentration of remaining chloroethane after fixed time intervals at room temperature.

The following results were obtained.

Time / min	[chloroethane] / mol dm^{-3} when [KOH] = 0.2 mol dm^{-3}
0	0.100
20	0.072
60	0.036
80	0.025
120	0.017

(i) Plot the data on suitable axes and use your graph to determine the order of reaction with respect to chloroethane.

(ii) The reaction is first order with respect to ethanolic potassium hydroxide.

On the same axes, sketch and label the graph for the reaction of chloroethane with 0.4 mol dm^{-3} of ethanolic potassium hydroxide.

(iii) Hence, write down the rate equation and state the units of the rate constant.

(iv) With the aid of a Boltzmann distribution curve, suggest and explain the effect on the rate of reaction when the reaction temperature is increased to 350 K.

[9]

5 **(c)** Propane undergoes substitution with chlorine to form two possible mono-chlorinated products. Draw the full structural formula of the two mono-chlorinated products and predict the ratio in which they are formed.

[2]

(d) Magnesium, silicon and chlorine are elements in the third period of the Periodic Table.

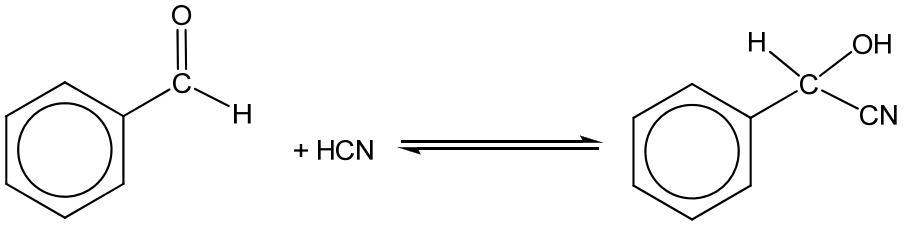
Explain the variation in melting point of these elements.

[4]

[Total: 20]

6 The formation of a cyanohydrin is a useful method in organic synthesis as the –CN group is capable of forming new functional groups.

The reaction between benzaldehyde and hydrogen cyanide to form a cyanohydrin is shown below.



cyanohydrin

(a) **(i)** State the condition required for the reaction.

(ii) Describe a chemical test to distinguish between benzaldehyde and the cyanohydrin formed above. Write balanced equations for any reactions that occur.

[4]

(b) **(i)** Write an expression for the equilibrium constant, K_c, for the reaction between benzaldehyde and hydrogen cyanide, stating its units.

(ii) 8.0 cm^3 of benzaldehyde was injected into a 2 dm^3 vessel containing 0.08 mol of HCN at 298 K and 1 atm.

Given the density of benzaldehyde is 1.04 g cm^{-3}, calculate the initial amount of benzaldehyde.

(iii) At equilibrium, the amount of the cyanohydrin was found to be 0.02 mol.

Using this amount and the amounts in **(ii)**, calculate a value for K_c.

[6]

(c) **(i)** Draw a 'dot-and-cross' diagram to show the bonding in hydrogen cyanide, stating its shape.

(ii) Suggest why hydrogen cyanide has a lower boiling point than water.

[4]

(d) Hydrogen cyanide is described as a weak acid.

(i) Explain, with the aid of an equation, what is meant by the term *weak acid*.

(ii) Calculate the hydrogen ion concentration, $[H^+]$, of a solution of hydrogen cyanide of pH 2.48.

6 (d) (iii) When Fe^{2+} was added into a solution of hydrogen cyanide, ferrocyanide ion was formed.

$$Fe^{2+} + 6CN^{-} \longrightarrow [Fe(CN)_6]^{4-}$$

ferrocyanide ion

This also resulted in the lowering of the pH of the solution.

Suggest this change in pH.

(iv) A buffer solution of hydrogen cyanide and its conjugate base can be prepared by mixing a reagent with aqueous hydrogen cyanide.

Suggest a reagent for the preparation of the buffer solution.

(v) Hence, with the aid of a equation, explain how the mixture solution can act as a buffer on addition of H^{+}.

[6]

[Total: 20]

************End of Paper************