| NAME | | Class | |
|---|---|---|---|

# ST ANDREW'S JUNIOR COLLEGE

# JC2 PRELIMINARY EXAMINATIONS

**Chemistry (9729)** **30 August 2019**

**Paper 2 Structured Questions** **2 hours**

Additional Materials: Data Booklet

## READ THESE INSTRUCTIONS:

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.

Answer **all** questions in the spaces provided on the Question Paper.

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:**

| Question | 1 | 2 | 3 | 4 | 5 | Total |
|---|---|---|---|---|---|---|
| Marks | 9 | 8 | 20 | 25 | 13 | 75 |

This document consists of **20** printed pages (including this page).

**1. (a)** **P**, **Q**, **R and S** are consecutive elements in Period 4.

The table below shows the first four ionisation energies (in kJ $mol^{-1}$) of the elements.

| Element | 1st I.E. | 2nd I.E. | 3rd I.E. | 4th I.E. | 5th I.E. |
|---|---|---|---|---|---|
| **P** | 908 | 1730 | 3828 | 5980 | 7970 |
| **Q** | 577 | 1980 | 2960 | 6190 | 8284 |
| **R** | 762 | 1540 | 3300 | 4390 | 9020 |
| **S** | 947 | 1798 | 2735 | 4837 | 6043 |

**(i)** Explain why the second ionisation energy of **Q** is higher than that of **R**. **[2]**

……

……

……

……

……

**(ii)** Explain why **P** is not considered to be a transition metal like most of the d-block metals. **[1]**

……

……

**(b)** The idea of covalent bonding was first described in 1916 by an American physical chemist Gilbert Newton Lewis. HCOC*l* is an example of a polar covalent molecule.

**(i)** Explain what is *covalent bonding*. **[1]**

……

……

……

**1. (b) (ii)** State what is meant by the term *polar* when applied to a covalent bond. **[1]**

……

……

**(iii)** State and explain with reference to the Valence Shell Electron Pair Repulsion theory, the shape of HCOC*l* molecule. **[2]**

……

……

……

……

**(iv)** The molecule of HCOC*l* contains both σ (sigma) and π (pi) bonds. Draw labelled diagrams to show how orbitals overlap to form

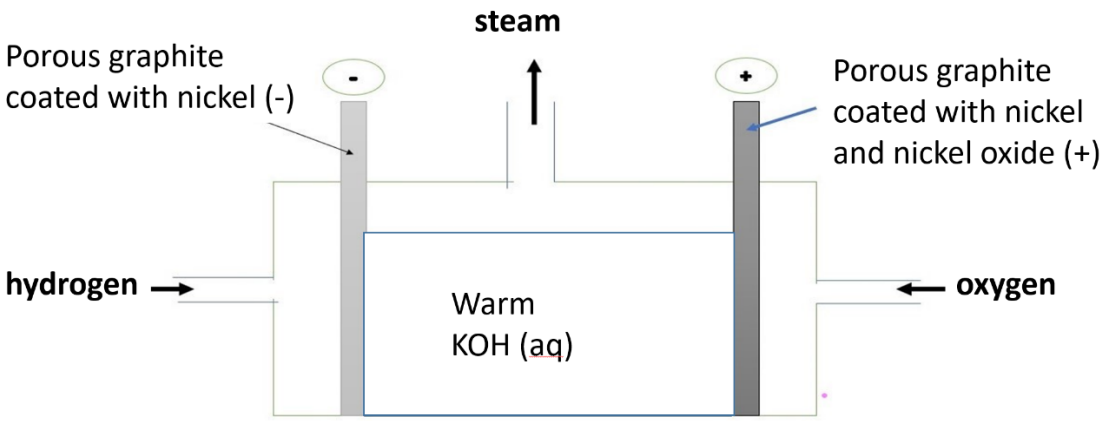
- a σ (sigma) bond

- a π (pi) bond

**[2]**

**[Total:9]**

**2** Below is a labelled diagram of a hydrogen-oxygen fuel cell in an alkaline electrolyte.




**(i)** Write the half equations for both electrodes and hence the overall equation. **[2]**

Cathode ……

Anode ……

Overall ……

**(ii)** Calculate $\Delta G^{\ominus}$ for the above reaction and state whether it is spontaneous. **[3]**

**2. (a) (iii)** The hydrogen-oxygen fuel cell produces 1.5 A of current. Hydrogen gas is contained in a 1 $dm^3$ tank at a pressure and temperature of 200 atm and 20 $^oC$ respectively. Determine the number of days the fuel cell can operate before the hydrogen gas runs out. Give your answer to the nearest whole number. You may assume there is an unlimited supply of $O_2$. **[3]**

**[Total:8]**

**3.** Spider silk is a protein fiber. Major amino acids in the silk proteins are alanine and glycine. Serine and glutamine are also present in significant quantities in some types of silk.
The table below shows the typical amino acids present in spider silk.

| Amino Acid | Formula of side chain (R in $RCH(NH_2)CO_2H$) |
|---|---|
| Glycine | –H |
| Alanine | $–CH_3$ |
| Serine | $–CH_2OH$ |
| Glutamine | $–CH_2CH_2CONH_2$ |

**(a) (i)** Glycine exists as crystalline solids. Draw the zwitterionic structure of glycine and account for the high melting point of glycine. **[2]**

……

……

……

**3.** **(a)** **(ii)** Write an equation to show the reaction between alanine and aqueous sodium carbonate. **[1]**

**(iii)** Suggest a chemical test to distinguish between serine and glutamine. **[2]**

……

……

……

……

**(b)** Natural spider silk has excellent mechanical properties. In a recent study, researchers discovered that graphene-based materials can be used to boost the properties of spider's silk up to three times the strength and ten times the toughness of the unmodified silks.

Graphene is the thinnest material known to exist, yet it is stronger than steel. It is made from only carbon and is a single layer of graphite just one atom thick as shown in Figure **3.1** below.

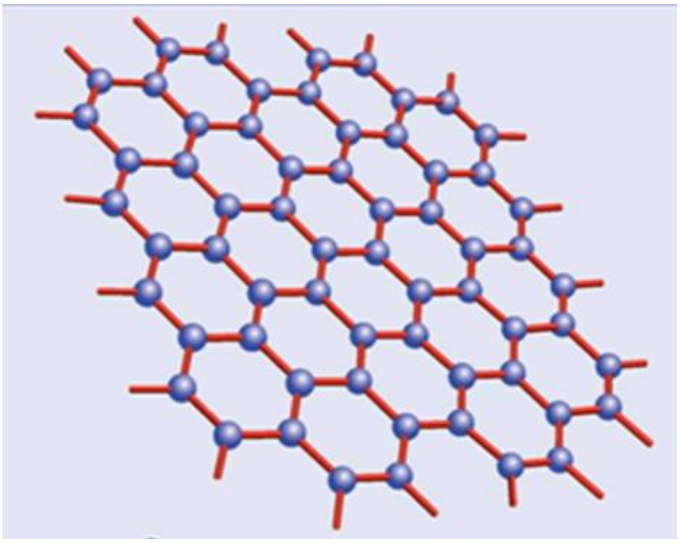


Figure **3.1**

**3. (b) (i)** With reference to structure and bonding, explain why graphene is strong. **[1]**

……

……

……

……

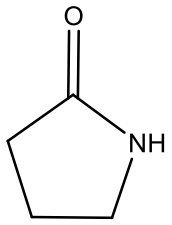
**(ii)** Since its discovery in 2004, graphene has been widely studied and manufactured as replacement materials for many touchscreen products. Suggest why graphene is a suitable touchscreen material in mobile phones. **[1]**

……

……

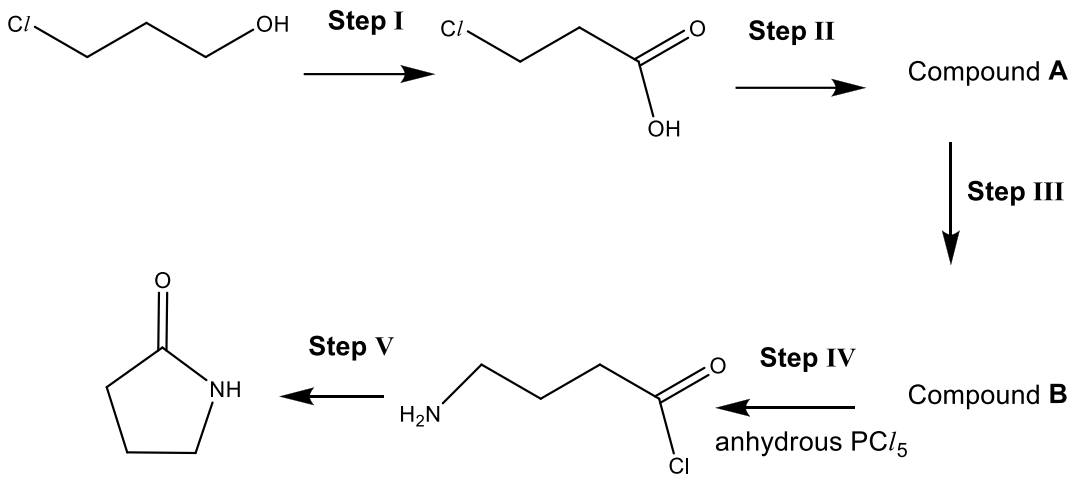
**(c)** Spider makes an excellent treat for a colony of marauding ants. To protect their homes, spiders coat their webs using a chemical called 2-pyrrolidone, which acts as a deterrent to many insects.

2-Pyrrolidone is a 5-membered cyclic amide (commonly known as lactam). It is a colourless liquid that is miscible with water and most common organic solvents.




2-Pyrrolidone

**3. (c)** 2-pyrrolidone can be synthesised using 3-chloropropan-1-ol as the starting organic compound as shown in the reaction scheme below:




**(i)** State the type of reaction in **Step V**. **[1]**

……

**(ii)** Suggest reagents and conditions for **Step I**, **II** and **III**. **[3]**

**Step I :** ……

**Step II :** ……

**Step III :** ……

**(iii)** Draw the structures of intermediate compounds **A** and **B.** **[2]**

| | |
|---|---|
| **A** | **B** |

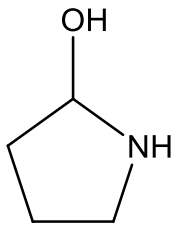
**3. (c) (iv)** With the aid of an equation, explain why anhydrous condition is necessary for the reaction in **Step IV**. **[1]**

……

……

……

**(v)** 2-pyrrolidirol can be synthesised from 2-pyrrolidone.




**2-pyrrolidirol**

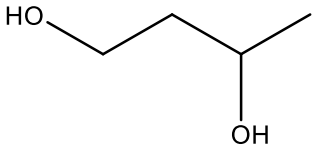
Deduce whether 2-pyrrolidone or 2-pyrrolidirol has a higher p$K_b$. **[2]**

……

……

……

**(vi)** Suggest a synthesis of 3-chloropropan-1-ol from 1,3-butandiol. **[4]**




**1,3-butandiol**

**[Total:20]**

**4** **(a)** Copper and iron are examples of native metals, which are found pure in its metallic form on its own or in alloys in nature.

Copper and iron form many complexes with a range of colours as shown in the table:

| complex | colour | complex | colour |
|---|---|---|---|
| $[Cu(NH_3)_4]^{2+}$ | dark blue | $[Fe(H_2O)_6]^{3+}$ | yellow |
| $[Cu(H_2O)_6]^{2+}$ | blue | $[Fe(CN)_6]^{3-}$ | red |

**(i)** Explain why $[Cu(H_2O)_6]^{2+}$ is blue. **[3]**

……

……

……

……

……

……

**(ii)** The oxidation state of iron in both $[Fe(CN)_6]^{3-}$ and $[Fe(H_2O)_6]^{3+}$ complexes is the same. However, they have different colours. Explain this observation. **[1]**

……

……

……

**4. (a) (iii)** Draw **fully labelled** diagrams of the following:

- One of the d-orbitals at the lower energy level in $[Cu(H_2O)_6]^{2+}$. Label the diagram "lower".
- One of the d-orbtials at the upper energy level in $[Cu(H_2O)_6]^{2+}$. Label this diagram "upper". **[2]**

**(b)** *Use of the Data Booklet is relevant to this question.*

$Fe^{2+}$ is commonly used to catalyse the reaction between $S_2O_8^{2-}$and $I^-$. In another similar reaction, peroxodisulfate(VI), $S_2O_8^{2-}$, reacts with tartrate ion, $[CH(OH)CO_2]_2^{2-}$, to give carbon dioxide and methanoate as shown in the following equation.

$$[CH(OH)CO_2]_2^{2-} + 3S_2O_8^{2-} + 2H_2O \rightarrow 2CO_2 + 2HCO_2^- + 6H^+ + 6SO_4^{2-}$$

The reaction is very slow, even when heated, hence a catalyst is used to speed up the reaction.

**(i)** Explain why the reaction is slow. **[1]**

……

……

**4. (b) (ii)** Given that the standard electrode potential for the following half-equation is

$2CO_2 + 2HCO_2^- + 6H^+ + 6e^- \rightleftharpoons [CH(OH)CO_2]_2^{2-} + 2H_2O \qquad E^\theta = +0.56\ V$

Using suitable equations, explain why $Mn^{2+}$ is a suitable catalyst for this reaction. **[2]**

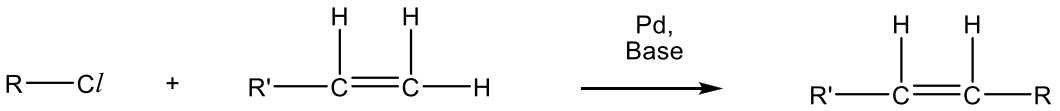
**(iii)** State the property of transition metal ions that enable them to function as a homogenous catalyst in the reaction. **[1]**

……

……

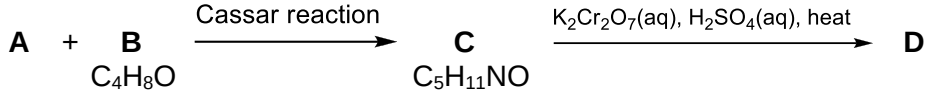
**4. (c)** Palladium is a transition element that is used as a catalyst in the Cassar reaction.

The Cassar reaction is a type of substitution reaction between an alkyl chloride and a terminal alkene in the presence of a base and a palladium catalyst.




*[R can be a substituted alkyl group containing –OH, –$NH_2$, –$NO_2$ ,–COOH]*

The following scheme shows the synthesis of **D** using Cassar reaction in one of the steps.




The table below shows the observations when **A**, **B** and **D** react with various reagents.

| | reaction | observations |
|---|---|---|
| **1** | **A** + HCl(aq) | colourless solution |
| **2** | **B** + $Br_2$(aq) | colourless solution |
| **3** | **D** + $Na_2CO_3$(aq) | Gas forms white ppt with $Ca(OH)_2$ |

**(i)** Name the functional group that reaction **1** shows to be present in **A** **[1]**

……

**(ii)** State the type of reaction that takes place in reaction **2** and name the functional group present in **B** **[1]**

……

**(iii)** **C** is able to exhibit cis-trans isomerism. Draw the structures of **A**, **B**, **C** and **D**. **[4]**

| | |
|---|---|
| **A** | **B** |
| **C** | **D** |

**4.** **(c)** **(iv)** Draw the structure of the product when $CH_3CH(CH_2Cl)CH_2CH_2CH{=}CH_2$ undergoes the Cassar reaction. **[1]**

**(d)** A solution containing $Cu^{2+}$ and $Zn^{2+}$ can be separated by selective precipitation.

The reagent used is hydrogen sulfide which behaves as a dibasic (diprotic) weak acid when in aqueous solution.

Aqueous hydrogen sulfide behaves as a dibasic acid.

$H_2S\,(aq) \rightleftharpoons H^+\,(aq) + HS^-\,(aq) \quad K_{a1} = 8.9 \times 10^{-8}$ mol dm$^{-3}$

$HS^-\,(aq) \rightleftharpoons H^+\,(aq) + S^{2-}\,(aq) \quad K_{a2} = 1.2 \times 10^{-13}$ mol dm$^{-3}$

Metal sulfides are precipitated by the following reaction.

$$M^{2+}(aq) + S^{2-}(aq) \rightleftharpoons MS(s)$$

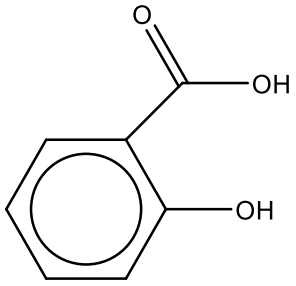
Relevant $K_{sp}$ values are given in the table below.

| Salt | $K_{sp}$ / mol$^2$ dm$^{-6}$ |
|---|---|
| CuS | $6.3 \times 10^{-36}$ |
| ZnS | $1.6 \times 10^{-24}$ |

**(i)** Given that a solution contains 0.0010 mol dm$^{-3}$ $Zn^{2+}$ and 0.0010 mol dm$^{-3}$ $Cu^{2+}$, determine the maximum sulfide concentration for each cation so that no precipitation occurs. **[1]**

**4. (d) (ii)** Given that $[H^+] = \sqrt{\frac{K_{a1}K_{a2}[H_2S]}{[S^{2-}]}}$ and using your answer in **(c)(i)**, calculate the maximum pH that must be maintained to separate $Zn^{2+}$ and $Cu^{2+}$ ions, given that the concentration of $H_2S$ in the solution is 0.0010 mol $dm^{-3}$. **[2]**

**(e)** The Trinder spot test is a diagnostic test used in medicine to determine exposure to salicylates, in particular, salicylic acid. The test involved the Trinder reagent which is mixed with a patient's urine. A coloured complex is formed if salicylates are present.



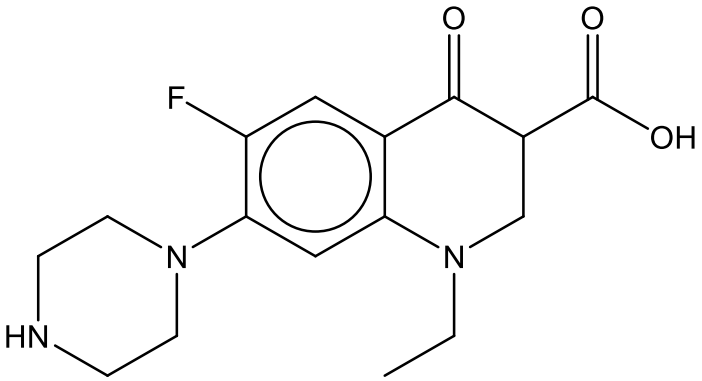

Salicylic acid

**(i)** Suggest the compound that is present in the Trinder reagent added to salicylic acid and state the observation when if the test is positive.

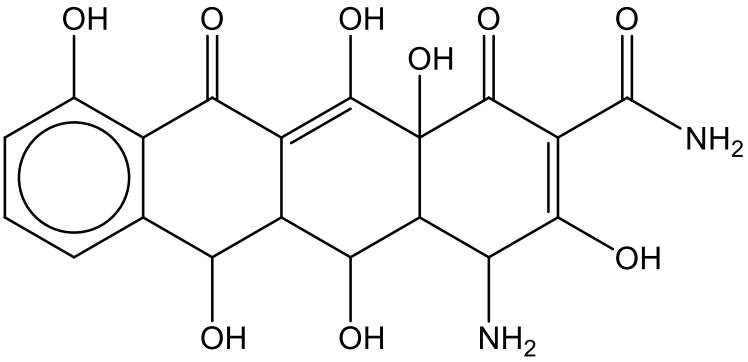
……..……

……..… **[2]**

**4. (e)** Another variation of the Trinder spot test has also been used to determine the presence of norfloxacin and oxytetracycline.




**norfloxacin**




**oxytetracycline**

**(ii)** State the number stereoisomers present in oxytetracycline. **[1]**

……..……

**(iii)** Suggest a chemical test to distinguish between oxytetracycline and norfloxacin. **[2]**

……..……

……..….

**[Total:25]**

**5.** Sodium alginate is a natural polymer extracted from brown seaweed. Figure **5.1** shows the simplified representation of a sodium alginate polymer.

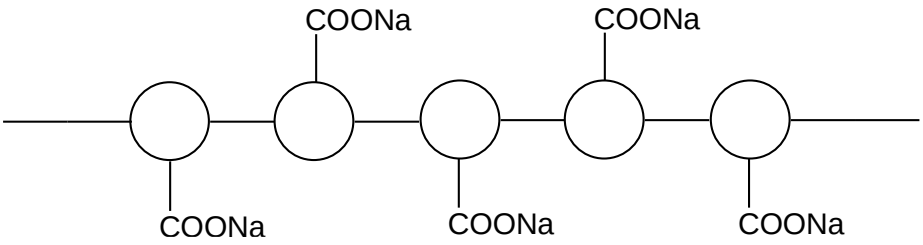



Figure **5.1** : simplified representation of sodium alginate polymer

In food chemistry, sodium alginate serves as a gel-forming agent as it can react with calcium salts to make “popping boba” in the bubble tea industry. This process is commonly known as spherification.

During spherification, a solution of sodium alginate is added to a solution of calcium salt. $Na^+$ ions are exchanged with $Ca^{2+}$ ions and the cross linked calcium alginate polymers forms as shown in Figure **5.2**.

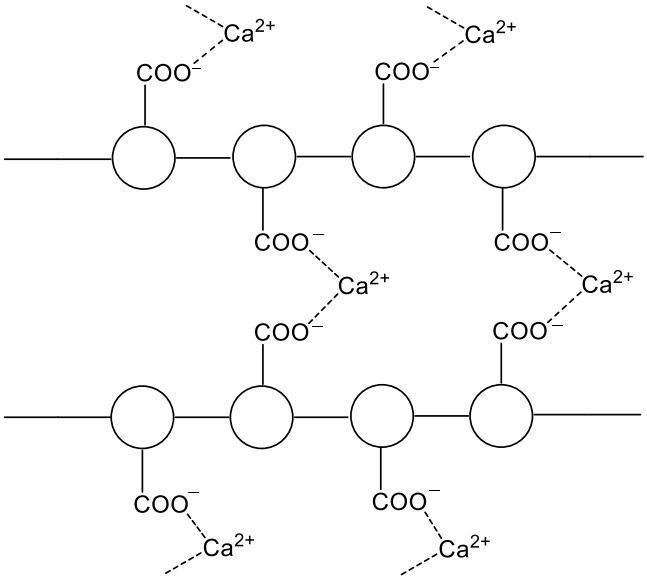



Figure **5.2**: simplified representation of cross-linked calcium alginate polymer

**(a) (i)** Cross-linking is the general term for the process of forming chemical bonds to join two polymer chains together. Explain, in terms of bonding, why $Ca^{2+}$ ions are able to cross-link the alginate polymers but $Na^+$ ions are unable to do so. **[1]**

……..……

……..…

**5. (a) (ii)** Explain why calcium alginate has a low solubility in water. **[1]**

……

……

……

**(b)** During spherification, the pH of the flavoured liquid used is important. Below a pH of 3.6, sodium alginate tends to react and the resultant solution will thicken which makes it difficult to form spheres.

Although $Ca^{2+}$ is crucial in helping the alginate to gel, excess $Ca^{2+}$ present can also cause the liquid to gel prematurely which is undesirable.

Table **5.3** shows the pH of various flavoured liquid.

Table **5.3**

| **Flavoured Liquid** | **pH** |
|---|---|
| cranberry juice | 2.3 |
| blueberry juice | 3.4 |
| tomato juice | 4.6 |
| watermelon juice | 5.2 |
| aloe vera juice | 6.1 |

**(i)** Cranberry juice is not suitable for spherification to work.

Suggest the type of reaction that takes place when sodium alginate is added to cranberry juice and hence explain why spherification will not occur in presence of cranberry juice. **[2]**

……

……

……

**5. (b) (ii)** A bubble tea shop wanted to make a "popping boba" by mixing 250 $cm^3$ of aloe vera juice with 300 $cm^3$ of blueberry juice. By determining the pH of the mixture, deduce if the spherification would happen. **[3]**

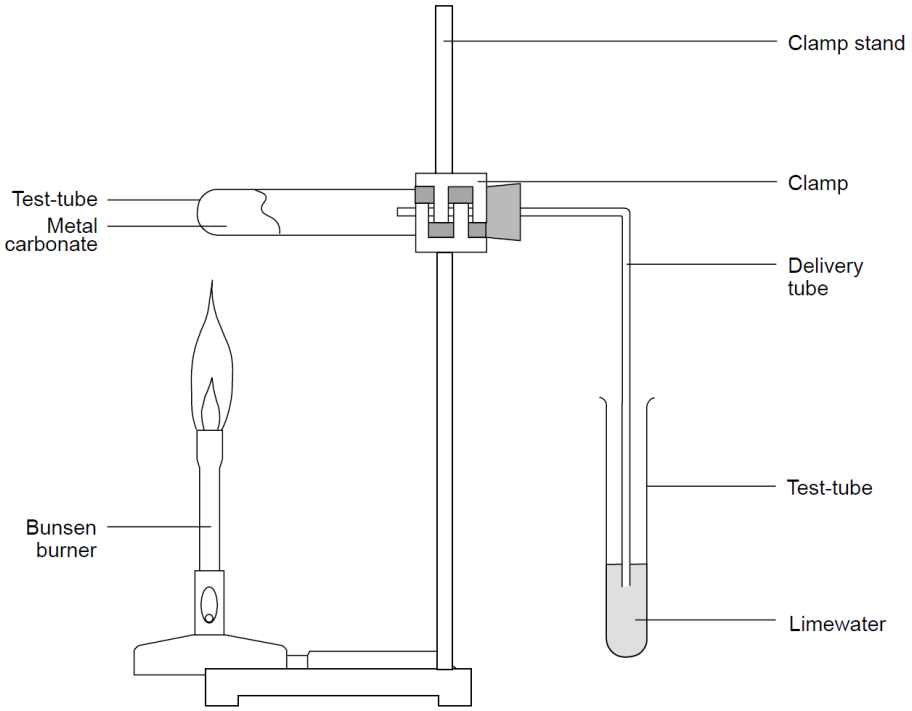
**(iii)** Hard water is water that has a high mineral content. It is formed when water percolates through deposits of limestone which are made up of calcium and magnesium carbonates and bicarbonates.
Suggest why spherification does not work well in hard water. **[1]**

……..……

……..…

**(iv)** Draw the dot-cross diagram for calcium bicarbonate $Ca(HCO_3)_2$. **[2]**

**5. (c)** A student set up the following experiment to investigate the thermal stability of magnesium and calcium carbonates:




Each of the metal carbonate is heated strongly for 5 min and the time taken for a white precipitate to form in limewater is recorded in the following table:

| Metal carbonate | Time taken (s) |
|---|---|
| **X** | 70 |
| **Y** | 40 |

**(i)** What are the identities of **X** and **Y**? **[1]**

**X**: ……

**Y**: ……

**(ii)** Explain the results. **[2]**

……

……

……

……

**[Total:13]**

**~END OF PAPER~**