Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2022

CHEMISTRY – ORDINARY LEVEL

TUESDAY, 21 JUNE – AFTERNOON 2:00 to 5:00

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300 MARKS

Answer any **six** questions.

All questions carry equal marks (50).

The information below should be used in your calculations.

Relative atomic masses (rounded): H = 1.0, C = 12, O = 16, Al = 27, Co = 59

Molar volume at s.t.p. = 22.4 litres

Avogadro constant = 6.0×10^{23} mol^{-1}

The use of the *Formulae and Tables* booklet approved for use in the State Examinations is permitted. A copy may be obtained from the superintendent.

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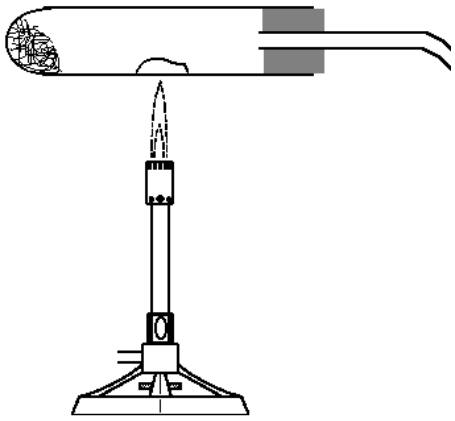
Section A

See page 1 for instructions regarding the number of questions to be answered.

1. (*a*) The diagram on the right shows part of an arrangement of apparatus and chemicals used to prepare ethene (C_2H_4) gas by dehydrating ethanol using a catalyst.



(*i*) Copy and complete the diagram by labelling the locations of the ethanol and the catalyst and showing how the ethene gas could have been collected.

(*ii*) Identify the catalyst used in this preparation.

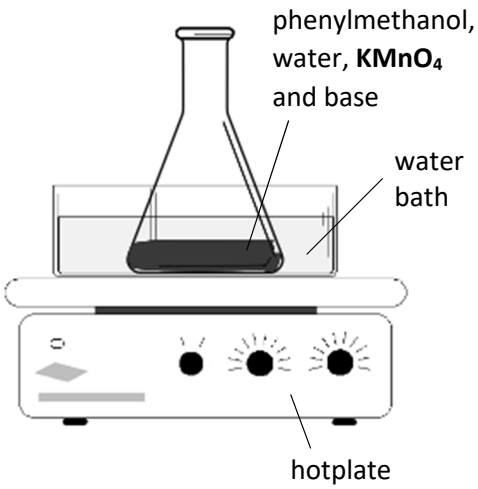
(*iii*) Describe how you could carry out a test for unsaturation on a sample of ethene. (29)

(*b*) The diagram below shows an arrangement of apparatus and chemicals for the oxidation of phenylmethanol (benzyl alcohol) to benzoic acid using $KMnO_4$ under basic conditions. In the process, insoluble MnO_2 was also formed.

Describe the appearance at room temperature of

(*i*) phenylmethanol,

(*ii*) benzoic acid.



After the oxidation reaction was complete the benzoic acid produced was separated from the reaction mixture.

Three of the reagents used in the preparation and isolation of the benzoic acid were: concentrated hydrochloric acid (**HCl**), sodium carbonate (Na_2CO_3) and sodium sulfite (Na_2SO_3).

Which one of these reagents

(*iii*) was the base added to the conical flask shown in the diagram above,

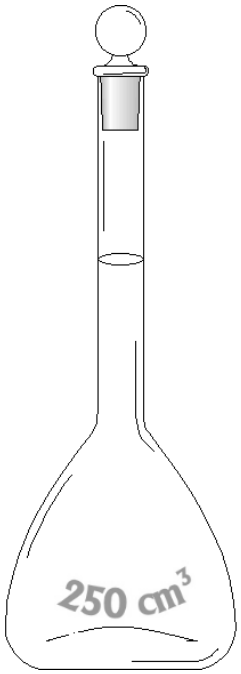
(*iv*) was added after the oxidation stage to reduce the MnO_2 to soluble Mn^{2+} ions?

What colour change was observed as

(*v*) the oxidation of the phenylmethanol took place,

(*vi*) the MnO_2 was converted to Mn^{2+}? (21)

2. A student prepared a 0.05 M sodium carbonate solution by dissolving a known mass of anhydrous sodium carbonate (**Na_2CO_3**) in deionised water in a beaker and transferring this solution to a 250 cm^3 volumetric flask. Then the solution in the flask was made up to the mark by adding more deionised water.



(*a*) What term is used to describe a solution whose concentration is accurately known? (5)

(*b*) Describe how all the sodium carbonate solution in the beaker was transferred to the volumetric flask and then made up accurately to exactly 250 cm^3 of solution with the same concentration throughout. (12)

(*c*) The mass of one mole of **Na_2CO_3** is 106 g.

(*i*) What is the mass of 0.05 moles of **Na_2CO_3**?

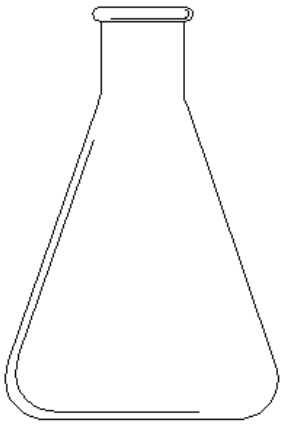
(*ii*) Calculate the mass of **Na_2CO_3** required to prepare 250 cm^3 of a sodium carbonate solution of exactly 0.05 M concentration. (9)

The sodium carbonate solution prepared by the student was then titrated with a hydrochloric acid (**HCl**) solution of unknown concentration. The acid was added from a burette to 25.0 cm^3 portions of the sodium carbonate solution in a conical flask.

The equation for the titration reaction is:

$$\mathbf{2HCl + Na_2CO_3 \rightarrow 2NaCl + H_2O + CO_2}$$

(*d*) How was the conical flask prepared for use in these titrations? (6)



(*e*) (*i*) Name an indicator suitable for use in these titrations.

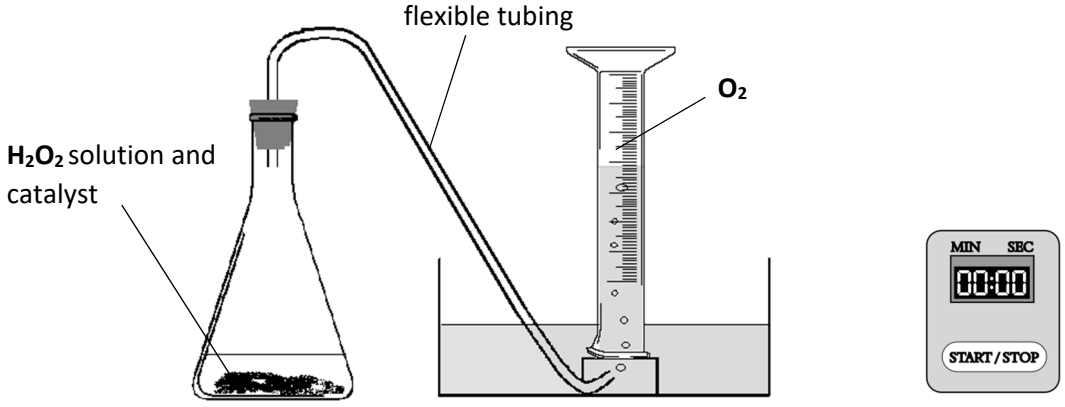
(*ii*) State the colour change observed in the conical flask at the end point using this indicator. (9)

(*f*) The average volume of **HCl** required to neutralise 25.0 cm^3 of the 0.05 M sodium carbonate solution was 20.1 cm^3.
Calculate the concentration, in moles per litre, of the **HCl** solution used. (9)

3. Solutions of hydrogen peroxide (H_2O_2) are unstable and decompose according to the following balanced equation:

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

A student measured the rate of decomposition, in the presence of a catalyst, of a hydrogen peroxide solution that had been in storage for some time. The student measured 25 cm^3 of the hydrogen peroxide solution into a flask and, having added a small quantity of a suitable catalyst, recorded the volume of oxygen collected at intervals over several minutes using the apparatus shown below.



(*a*) (*i*) Identify a suitable catalyst for the decomposition of H_2O_2.

(*ii*) Describe the appearance of the catalyst.

(*iii*) Explain how the catalyst could have been added to the hydrogen peroxide solution in the flask without loss of oxygen gas. (18)

(*b*) Data obtained in the test are given in the table.

Time (minutes)	0	1	2	3	4	4.5	5	6	7
Volume O_2 (cm^3)	0	37.5	63	82	94	97	98	98	98

(*i*) Plot a graph (on graph paper) of volume of O_2 (*y*-axis) *versus* time.

From your graph

(*ii*) estimate the time taken to collect 50 cm^3 of oxygen,

(*iii*) find the average rate of reaction over the first 2.5 minutes (in cm^3 of O_2 per minute). (24)

(*c*) According to the label on the H_2O_2 solution, every 25 cm^3 of the solution releases 250 cm^3 of oxygen, measured at room temperature and pressure, on complete decomposition.
State and explain whether the solution had fully or partially decomposed during storage. (8)

Section B

See page 1 for instructions regarding the number of questions to be answered.

4. Answer **eight** of the following (*a*), (*b*), (*c*), etc. (50)

(*a*) Name the Russian scientist who, in the 1860s, made a table of the elements, listing them according to increasing atomic weight (mass) and grouping elements with similar properties together.

(*b*) Write the chemical formula for

(*i*) potassium bromide,

(*ii*) beryllium chloride.

(*c*) Some buses run on hydrogen gas which could be obtained from the electrolysis of water.
Write a balanced equation for the formation of hydrogen gas from water.

(*d*) Name the piece of equipment used to measure accurately the energy content of foods and fuels.

(*e*) A water supply containing **$CaCl_2$** is described as hard water. What is hard water?
Is the hardness of this water supply temporary or permanent?

(*f*) Identify the nitrate salt in the reagent used to test for the presence of chloride anions in aqueous solution.

(*g*) Name a process used to extract clove oil from cloves.

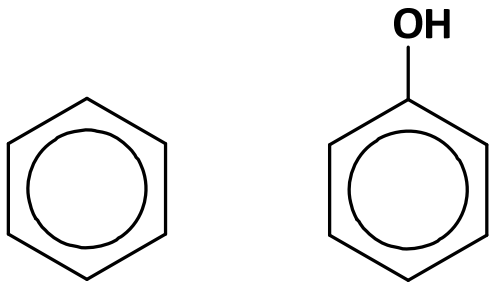
(*h*) 2,2,4-trimethylpentane has a higher <u>octane number</u> than heptane.
Explain the underlined term.

(*i*) Cobalt blue is a pigment containing cobalt(II) aluminate (**$CoAl_2O_4$**) and has been used for centuries as a colouring agent in blue and white Chinese porcelain.
Find the percentage by mass of cobalt in **$CoAl_2O_4$**
to the nearest whole number.

(*j*) A sherbet powder is composed of sugar, citric acid and **$NaHCO_3$**. When it is added to water the powder disssolves and the citric acid reacts with the **$NaHCO_3$**. The overall process is *endothermic.*
Does the temperature of the sherbet and water reaction mixture increase or decrease?

This question continues on the next page.

(*k*) The diagram below shows the structure of a benzene molecule on the left and the structure of a molecule of the antiseptic compound phenol on the right. The molecular formula of benzene is $\mathbf{C_6H_6}$. Write the molecular formula of phenol.



(*l*) Answer part **A** *or* part **B**.

A Indicate which one of the following chemical industries you studied:

$\mathbf{NH_3}$ manufacture $\mathbf{HNO_3}$ manufacture **MgO** manufacture

Give a major use of the main product of the industry you studied.

or

B Give an example of a covalent macromolecular crystal.

5. Refer to pages 79 and 81 of the *Formulae and Tables* booklet when answering this question.

Linus Pauling calculated a set of electronegativity values and used them to explain some aspects of chemical bonding.

(*a*) The octet rule states that many atoms tend to form compounds by gaining, losing or sharing electrons, giving them eight valence electrons, and thus the same arrangement of electrons as one of the noble gases.

Identify the type of bonding that arises

(*i*) between the ions formed when atoms lose and gain electrons,

(*ii*) when atoms share electrons.

When two hydrogen atoms join to form a $\mathbf{H_2}$ molecule,

(*iii*) state whether the **H** atoms that bond achieve a noble gas arrangement of electrons,

(*iv*) explain whether the octet rule is satisfied. (12)

(*b*) Define electronegativity. (6)

(*c*) Write down the arrangement of electrons in the main energy levels in an atom of

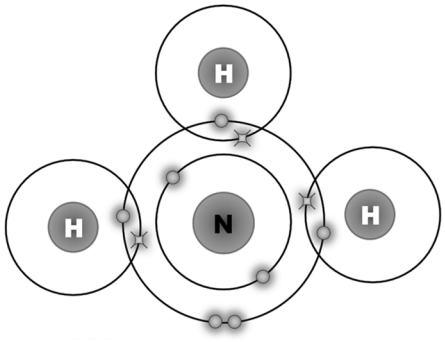
(*i*) sodium,

(*ii*) fluorine.

(*iii*) Use electronegativity values to predict the type of bonding in sodium fluoride (**NaF**).

(*iv*) The octet rule is fully satisfied in **NaF**. Using a dot and cross diagram, or otherwise, explain how the bonding in **NaF** arises. (21)

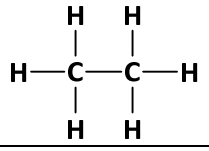
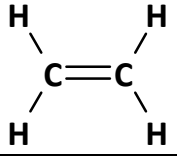
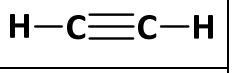
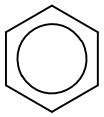
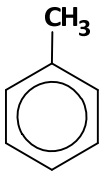
(*d*) The diagram represents the arrangement of electrons in an ammonia ($\mathbf{NH_3}$) molecule.



(*i*) How many pairs of bonding electrons are there around the nitrogen atom in an ammonia molecule?

(*ii*) What is the shape of an $\mathbf{NH_3}$ molecule? (11)

6. Consider the structural formulae of the five hydrocarbon compounds **A** to **E** in the table.

A	
B	
C	
D	
E	

(*a*) Explain the underlined term. (5)

(*b*) Give the IUPAC names for compounds **A**, **C** and **E**. (9)

(*c*) (*i*) Identify **two** compounds from the table that are gaseous at room temperature.

(*ii*) Identify **two** aromatic hydrocarbons in the table. (12)

(*d*) Which one of the compounds in the table is used industrially

(*i*) in cutting and welding metals,

(*ii*) to make addition polymers? (6)

(*e*) All hydrocarbons form the same two products when burned in a plentiful supply of oxygen.

Copy, complete and balance the following equation for the combustion of compound **C** in excess oxygen.

$$C_2H_2 + O_2 \rightarrow$$ (9)

(*f*) (*i*) Draw the structural formula for the second member of the homologous series to which **B** belongs.

(*ii*) In the structure you have drawn, clearly indicate any carbon atoms in tetrahedral geometry. (9)

7. (*a*) Define (*i*) an acid, (*ii*) a base.

(*iii*) Define pH.

A 0.03 M **HCl** solution with a pH value of 1.5 was diluted by adding deionised water until its concentration was 0.003 M.

(*iv*) Calculate the pH of the 0.003 M **HCl** solution, correct to one decimal place. (20)

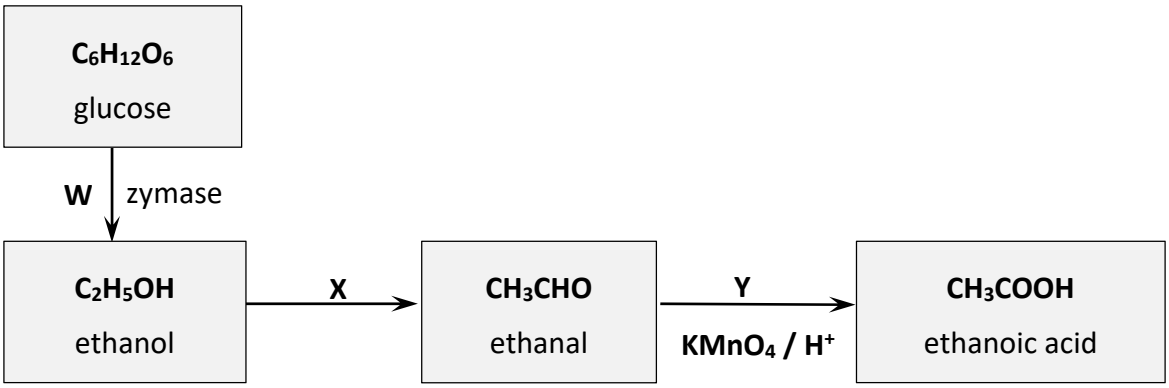
(*b*) The following terms are omitted from the passage below.

decreases **0** **H^+** **1** **OH^-** **increases** **10**

Write in your answerbook the omitted term corresponding to each of the letters **A** to **G**.

The pH scale ranges from **A** to 14, where a pH value of 7 means that there are equal numbers of **H^+** and **B** ions in a solution. The lower the pH value, the more **C** ions are present. The calculation referred to above illustrates that because the pH scale is logarithmic, a change in pH of **D** unit is observed when the concentration of **H^+** ion in solution changes by a factor of **E**. It can also be noted from the calculation that when the concentration of **H^+** ion decreases, the pH value **F**. During a titration, as more **H^+** ions are added to an alkaline solution in a conical flask, the pH value of the solution in the flask **G** until the end point is reached. (30)

8. Study the reaction scheme below and answer the questions that follow.



(*a*) Reaction **W** is a fermentation process used to make the ethanol in alcoholic drinks.

(*i*) Fermentation of glucose to ethanol involves the <u>enzyme</u> zymase contained in yeast. Explain the underlined term.

(*ii*) Give a major use for ethanol, other than in alcoholic beverages.

(*iii*) When one glucose ($C_6H_{12}O_6$) molecule is fermented by the action of zymase, it is broken down into **two** ethanol (C_2H_5OH) molecules and a number of CO_2 molecules.
How many carbon atoms from one glucose molecule end up forming CO_2? (17)

(*b*) Reaction **X** occurs in the human body as ethanol is metabolised.

(*i*) How many atoms, of which element, are lost when a molecule of ethanol is converted into a molecule of ethanal?

(*ii*) Classify this reaction as an oxidation reaction or as a reduction reaction.

(*iii*) How does the geometry around the carbon atom to which the oxygen is attached change as reaction **X** occurs? (15)

(*c*) Reaction **Y** occurs when some ethanal is added to warm dilute acidified $KMnO_4$ in a test-tube.

(*i*) How many atoms, of which element, are gained when a molecule of ethanal is converted into a molecule of ethanoic acid?

(*ii*) Classify this reaction as an oxidation reaction or as a reduction reaction.

(*iii*) What colour change is observed during reaction **Y**? (18)

9. (*a*) Describe how you could carry out a flame test to confirm the presence of sodium in a sample of a salt. (12)

(*b*) A salt was made by the reaction of sodium metal and chlorine gas as follows:

$$\mathbf{2Na + Cl_2 \rightarrow 2NaCl}$$

Define in terms of electron transfer

(*i*) oxidation,

(*ii*) reduction.

(*iii*) Identify the reducing agent in the redox reaction above. (12)

(*c*) Another redox reaction took place when magnesium ribbon was added to an aqueous copper(II) sulfate solution. This reaction is described by the balanced equation:

$$\mathbf{Mg + Cu^{2+} \rightarrow Mg^{2+} + Cu}$$

(*i*) What was observed during this displacement reaction?

(*ii*) Which metal, copper or magnesium, is shown by this reaction to be the more easily oxidised and therefore higher up the electrochemical series?

(*iii*) Would you expect the following displacement reaction to occur when copper metal is added to a sodium chloride solution?

$$\mathbf{Cu + 2Na^{+} \rightarrow Cu^{2+} + 2Na}$$

Explain your answer. (26)

10. Answer any **two** of the parts (*a*), (*b*) and (*c*). (2 × 25)

(*a*) The element hydrogen has three naturally occurring isotopes, $^{1}_{1}\mathbf{H}$, $^{2}_{1}\mathbf{H}$, and $^{3}_{1}\mathbf{H}$.

What is meant by (*i*) the atomic number, (*ii*) the mass number, of an atom?

(*iii*) What are isotopes?

(*iv*) In terms of subatomic particles, how do $^{1}_{1}\mathbf{H}$ and $^{2}_{1}\mathbf{H}$ differ?

(*v*) Define radioactivity.

(*vi*) $^{3}_{1}\mathbf{H}$ is radioactive and decays by emitting a beta particle.

What is a beta particle? (25)

(*b*) The colourless gas **N_2O_4** decomposes into the brown gas **NO_2** and the following chemical equilibrium is established at room temperature.

$$\mathbf{N_2O_4}\,(g) \rightleftharpoons \mathbf{2NO_2}\,(g)$$

(*i*) Explain the underlined term.

(*ii*) Why is a chemical equilibrium described as being dynamic?

(*iii*) Write the equilibrium constant (K_c) expression for this reaction.

At a certain pressure and temperature an equilibrium mixture of **N_2O_4** and **NO_2** was light brown. The mixture was allowed to expand into a vessel of larger volume, decreasing the pressure but keeping the temperature constant. When equilibrium was re-established the reaction mixture was darker than before.

(*iv*) State Le Châtelier's principle.

(*v*) Use this principle to explain why there was more **NO_2** in the final reaction mixture than when equilibrium was first established. (25)

(*c*) The NASA Perseverance Rover that landed on Mars in 2021 contained MOXIE, a small test unit designed to extract oxygen by electrolysis from the Martian atmosphere, which is mostly carbon dioxide, according to the following balanced equation.

$$\mathbf{2CO_2 \rightarrow O_2 + 2CO}$$

In a test conducted in April 2021 on Mars, MOXIE produced 5.4 g of **O_2** in one hour.

(*i*) How many moles of oxygen (**O_2**) are there in 5.4 g?

(*ii*) What volume would this quantity of oxygen occupy, measured at s.t.p.?

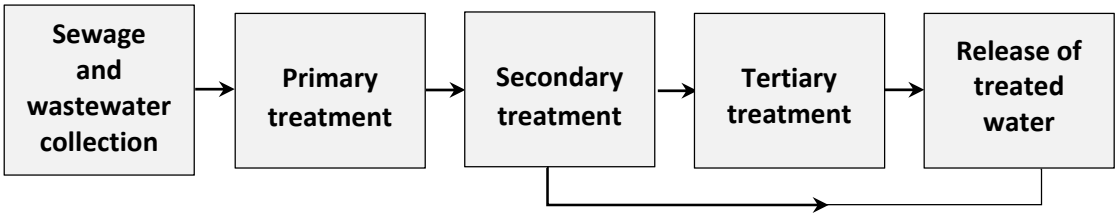
(*iii*) How many molecules are there in this quantity of oxygen?

(*iv*) How many moles of carbon dioxide were used up in the electrolysis reaction to produce this quantity of oxygen?

(*v*) What mass of **CO** by-product was produced by MOXIE in one hour? (25)

11. Answer any **two** of the parts (*a*), (*b*), (*c*) and (*d*). (2 × 25)

(*a*) The following flow chart shows the various stages of sewage treatment.



(*i*) Describe one process carried out during primary treatment of sewage.

(*ii*) What happens during secondary treatment?

(*iii*) Tertiary treatment is often designed to remove compounds of two particular elements from sewage. Identify one of these elements.

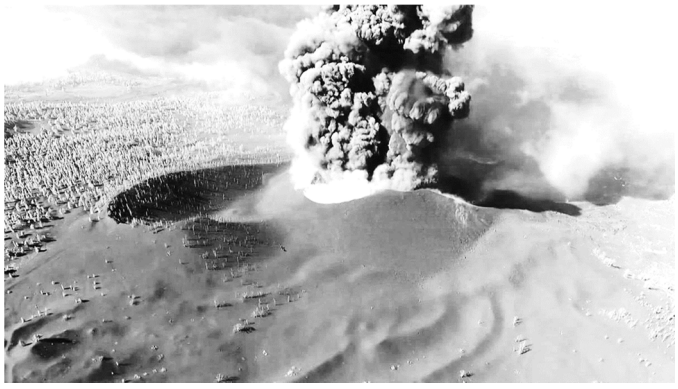
(*iv*) What problem could occur if compounds of these elements were present in the treated water when it is released?

(*v*) Why is tertiary treatment not always carried out? (25)

(*b*) (*i*) What are the three states of matter?

(*ii*) Erupting volcanoes release rivers of hot molten rock that cool and solidify as they move away from the volcano cone.
Compare the freedom of movement of the particles in the molten lava and the solidified rock.

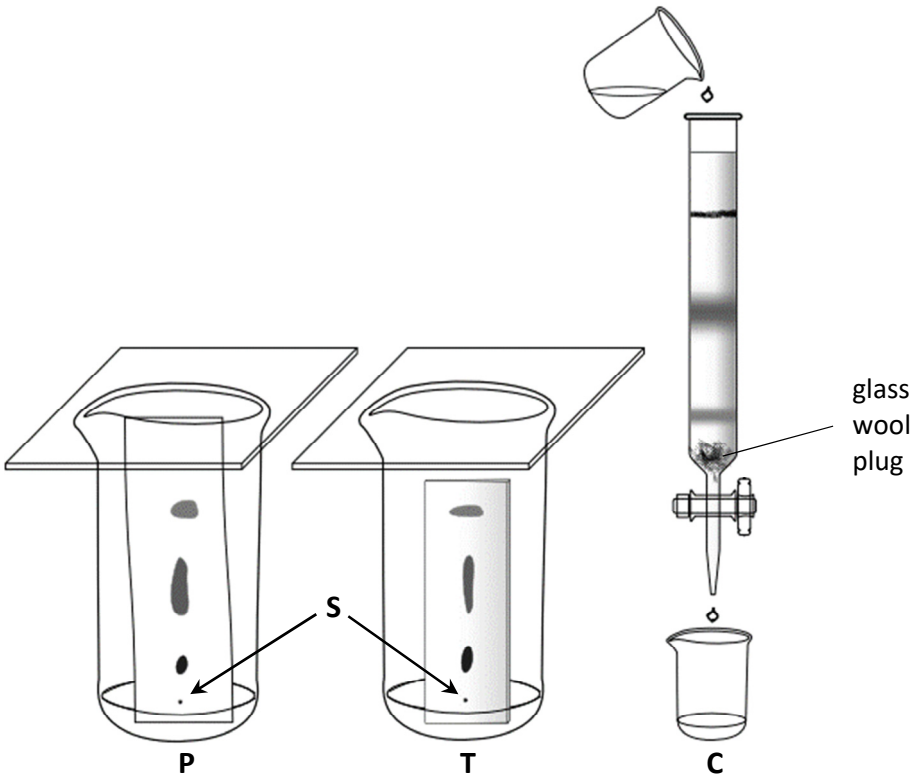
(*iii*) What term is used to describe the spreading out of smoke in air as shown in the photograph of the 2021 eruption of the Cumbre Vieja volcano in the Canary Islands?



(*iv*) A sample of gas was collected from a hot volcano plume. At 20 °C and at atmospheric pressure this sample of gas had a volume of 1.5 litres.
Calculate, correct to one decimal place, the volume occupied by this gas while still in the plume where the temperature was 750 °C and the pressure was also atmospheric pressure.

Name the law you used to calculate your answer. (25)

(*c*) The technique of chromatography is used to separate the components of a mixture. The diagrams below show the separation of a mixture of coloured components by paper chromatography **P**, thin-layer chromatography **T** and column chromatography **C**.



Copy a diagram of **one** of the chromatographic methods **P**, **T** or **C** shown above into your answerbook. Answer part (*i*) *or* part (*ii*) *and* parts (*iii*) to (*vii*) below.

(*i*) In **P** *or* **T** why does the original sample spot **S** have to be above the solvent level?

or

(*ii*) In **C** what is the purpose of the glass wool plug?

(*iii*) State what material acts as the stationary phase in the separation you have drawn.

(*iv*) Does the mobile phase move up or down through the stationary phase in the separation you have drawn?

(*v*) Label with an **X** on your diagram the component most strongly adsorbed by the stationary phase during the separation.

(*vi*) Label with a **Y** on your diagram the component carried fastest by the mobile phase.

(*vii*) Describe the result you would expect to get if the components of the mixture were all insoluble in the mobile phase. (25)

This question continues on the next page.

(*d*) Answer part **A** *or* part **B**.

A

In a chemical reaction between substances **X** and **Y**, substances **C** and **D** are formed according to the following balanced equation.

$$\mathbf{X + Y \rightarrow C + D}$$

In industry, substances **X** and **Y**, dissolved in an organic solvent, react together in a steel vessel equipped with a stirring mechanism. A number of hours later the **C** and the **D** produced are separated from the reaction mixture and from each other and purified. The reaction vessel is emptied of unreacted **X** and **Y** and of solvent, cleaned, and the process is repeated. **D** is the co-product in the industrial manufacture of **C**.

(*i*) Is the manufacture of **X** as described above a batch process or a continuous process?

(*ii*) Why is steel a suitable material for reaction vessels in the chemical industry?

(*iii*) Suggest two possible ways of increasing the rate of production of **C**.

(*iv*) What happens to co-products of the chemical industry such as **D** after they are isolated and purified?

(*v*) Suggest what could be done with the solvent and any unreacted **X** and **Y** to reduce manufacturing costs. (25)

or

B

Thin sheets of aluminium are used to wrap foodstuffs, e.g. chocolate. Plastic cling film used to wrap food is sometimes made from poly(chloroethene) or PVC, an addition polymer.

The following terms are associated with material properties:

electrical conductivity malleability
lustre chemical inertness melting point

(*i*) Explain the terms *malleability* and *lustre*.

(*ii*) Select **two** of the five properties above that make aluminium a suitable material for wrapping food.

(*iii*) An addition polymer is made by joining together many monomer units each of which contains a carbon-carbon double bond.
Draw the structure of chloroethene, the monomer for making poly(chloroethene).

(*iv*) Draw two repeating units of poly(chloroethene). (25)

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Leaving Certificate – Ordinary Level

Chemistry

Tuesday, 21 June

Afternoon, 2:00 – 5:00