Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2021

CHEMISTRY – ORDINARY LEVEL

TUESDAY, 22 JUNE – AFTERNOON 2:00 to 5:00

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, N = 14, O = 16, Na = 23, Cl = 35.5

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

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

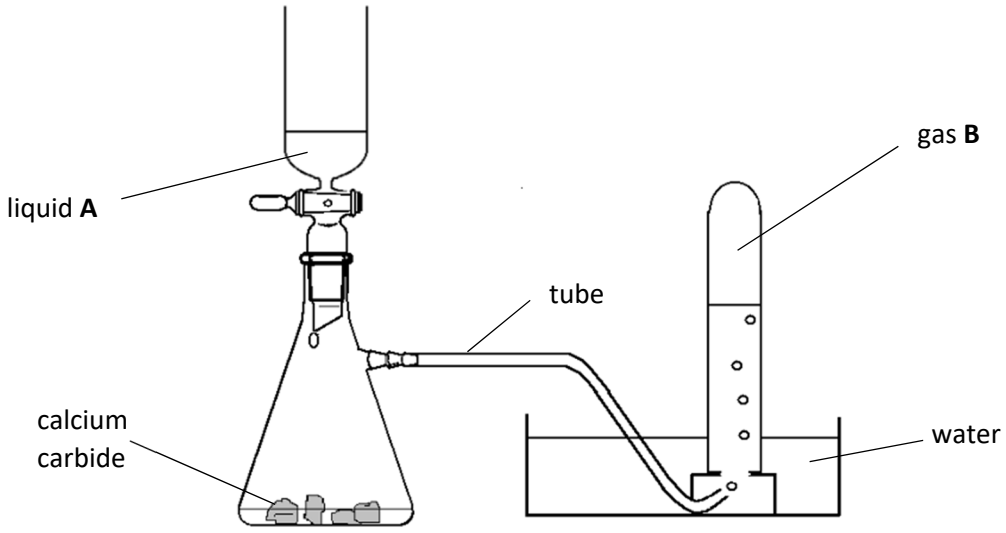
The use of the *Formulae and Tables* booklet approved for use in the State Examinations is permitted. A copy may be obtained from the superintendent.

Section A

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

1. Before battery-powered lamps became available in the early 1900s, *carbide* lamps that made use of a chemical reaction to produce a flammable hydrocarbon gas that burned with a bright, sooty flame were commonly used on bicycles and motor cars.

The apparatus shown in the diagram can be used to make and collect this hydrocarbon gas **B** in the school laboratory.



(*a*) Identify

(*i*) liquid **A**,

(*ii*) gas **B**. (11)

(*b*) Describe what happens in the reaction flask when liquid **A** is added slowly to calcium carbide. (6)

(*c*) (*i*) What does the method of collection of **B** tell you about its solubility in water?

(*ii*) Why are the first few test-tubes of gas produced **not** used in tests? (9)

(*d*) Gas **B** is <u>unsaturated</u>.

(*i*) Explain the underlined term.

(*ii*) Describe how you could carry out a test for unsaturation on a sample of **B**. (15)

(*e*) When burned in air, **B** produces a bright, sooty flame but **B** must be burned in pure oxygen if its flame is to be suitable for welding and cutting metal.

Give two characteristics of the flame when **B** is burned in pure oxygen. (9)

2. In order to prepare a *pure* sample of sodium chloride, a student first carried out one rough and two accurate titrations of 25.0 cm^3 portions of a sodium hydroxide solution with 0.3 M hydrochloric acid solution. A burette was used to add the **HCl** to the **NaOH** in a conical flask until an indicator showed that the end point had been reached.

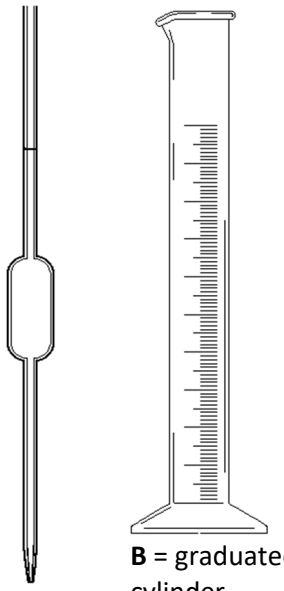
The equation for the titration reaction is:

HCl + NaOH → NaCl + H_2O

(*a*) (*i*) Identify the pieces of apparatus **A** and **C** shown on the right.

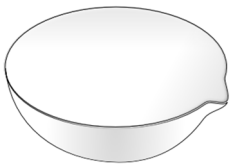
(*ii*) Would **A** or **B** have been more suitable to measure accurately 25.0 cm^3 of the **NaOH** solution into the conical flask? Explain your answer.

(*iii*) How should the piece of apparatus you selected in (*ii*) have been rinsed before using it to measure out the **NaOH** solution? (18)



A

B = graduated cylinder



C

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

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

(*iii*) What substances are present in the conical flask at the end point of the titration? (15)

(*c*) On average 23.0 cm^3 of 0.3 M **HCl** solution were required to neutralise the 25.0 cm^3 portions of the **NaOH** solution.

Calculate the concentration, in moles per litre, of the **NaOH** solution used. (9)

(*d*) The student then added exactly 23.0 cm^3 of the 0.3 M **HCl** to another 25.0 cm^3 portion of the **NaOH** solution in the conical flask, this time without the indicator.

(*i*) How could the student have then obtained a pure, dry sample of sodium chloride using the piece of apparatus **C**?

(*ii*) Calculate the mass of **NaCl** produced if 0.0069 moles of **NaCl** were formed in the neutralisation reaction. (8)

3. A thermometer was inserted through the plastic lid of an insulated cup containing 100 cm^3 of 1.0 M sodium hydroxide solution. A timer was started and the temperature of the contents of the cup was measured and recorded at 0.5-minute intervals for a total of 5 minutes. Between the 2 minute and 2.5 minute temperature readings, 100 cm^3 of 1.0 M hydrochloric acid solution were quickly added to the cup and the mixture was stirred. The initial temperature of the **HCl** was 16.0 °C.

The results are given in the table.

The balanced equation for the neutralisation reaction between hydrochloric acid and sodium hydroxide is as follows:

HCl + NaOH → NaCl + H_2O

The overall temperature change observed was used to calculate the heat of reaction (ΔH) for this neutralisation.

Time (minutes)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Temperature (°C)	16.0	16.0	16.0	16.0	16.0	22.1	22.7	22.6	22.5	22.4	22.3

(*a*) Plot a graph (on graph paper) of temperature *versus* time (*x*-axis). (15)

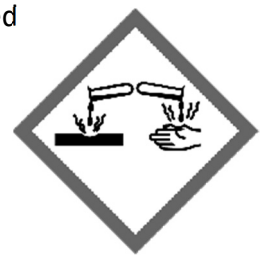
(*b*) (*i*) Estimate the maximum temperature change as a result of the reaction.

(*ii*) Is the neutralisation of sodium hydroxide solution by hydrochloric acid exothermic or endothermic?

Justify your answer. (12)

(*c*) Why is an insulated cup, like that shown above, a suitable container for this experiment? (6)

(*d*) The container in which the 1.0 M **NaOH** solution was provided carried the warning pictogram shown on the right.



(*i*) What chemical hazard is indicated by this pictogram?

(*ii*) Describe one precaution that should have been taken when using this solution. (12)

(*e*) In this experiment 0.1 moles of **HCl** were neutralised. The heat change was calculated to be 5.7 kJ. Find ΔH in kJ mol^{-1} for the reaction. (5)

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*) Some carbon atoms have a greater mass than others. Explain.

(*b*) Some elements are radioactive. Explain the underlined term.

(*c*) An aerial distress flare is essentially a type of firework designed to burn bright red, high in the sky, as shown on the right, for at least 40 seconds.

Name a metal whose salts have a red flame colour.

(*d*) Explain why the atomic radius of lithium is larger than that of fluorine.

(*e*) What is the relationship between the volume and the temperature (in Kelvin) of a fixed mass of gas at constant pressure?

(*f*) In which state of matter do the molecules

(*i*) move around fastest,

(*ii*) only vibrate about fixed positions?

(*g*) 'Methanal (**HCHO**), ethanoic acid (**CH_3COOH**) and glucose (**$C_6H_{12}O_6$**) all have the same empirical formula.'
Is the statement above true or false? Explain.

(*h*) Why are mercaptans added to natural gas and to **LPG** before they are supplied to customers?

(*i*) Toothpastes containing fluoride ions help protect against tooth decay. Find the mass of fluoride in 1.0 cm^3 of a toothpaste that has a fluoride concentration of 1,360 p.p.m. (mg l^{-1}).

(*j*) Why should the release of sewage and industrial waste or silage run-off into waterways be avoided?

This question continues on the next page.

(*k*) Supply the missing words in the following statement:
'In organic chemical synthesis specific bonds in the reactant molecules are _____ and specific bonds in the product molecules are _____.'

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

A Give one source of the sulfuric acid that is sometimes contained in acid rain.

or

B Why are steel bathroom taps often coated with a layer of chromium metal?

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

(*a*) (*i*) Define electronegativity.

(*ii*) Write down the electronegativity values of hydrogen, beryllium and oxygen. Use these values to predict the type of bonding expected in **BeO** and **H_2O**. (15)

(*b*) **BeO** is solid at room temperature and melts at 2,507 °C.
Would you expect molten **BeO** to be able to conduct electricity?
Explain your answer. (6)

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

(*i*) beryllium,

(*ii*) oxygen.

(*iii*) Using a dot and cross diagram, or otherwise, show how the bonding in **BeO** arises. (12)

(*d*) (*i*) Hydrogen (**H_2**) has non-polar single covalent bonding.
Explain the underlined term.

(*ii*) Oxygen (**O_2**) also has covalent bonding.
Use a dot and cross diagram to show the arrangement of the electrons in an **O_2** molecule.
(Electrons in the first main energy levels need not be shown.)

(*iii*) Why would you expect **O_2** to have low solubility in water? (17)

6. Crude oil is a useful resource which is recovered from sedimentary rock by drilling. Crude oil is a mixture of hydrocarbons and is separated into a number of different fractions during oil refining. Three of the fractions obtained from the fractional distillation of crude oil are:

gas oil (diesel oil) **light gasoline** **kerosene**

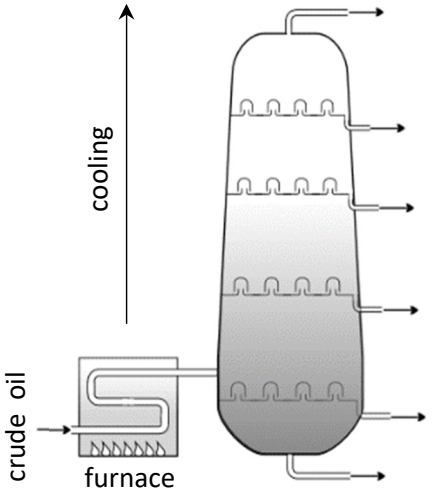
(*a*) Explain the underlined term. (5)

(*b*) List the three fractions named above in order of increasing boiling point. (6)

(*c*) As they separate in a fractionating column, where (high up or low down) would you expect to collect the hydrocarbons

(*i*) with the fewest carbon atoms,

(*ii*) with the highest boiling points? (12)



(*d*) Which of the three fractions named above

(*i*) is used as a fuel for jet aircraft,

(*ii*) is often catalytically cracked to make smaller molecules for use in petrol? (9)

(*e*) (*i*) What term is used as a measure of the tendency of a fuel to cause knocking in an engine?

(*ii*) Why were lead compounds previously added to petrol?

(*iii*) Why was the addition of lead compounds to petrol discontinued? (18)

7. Water undergoes various treatments to make it safe for supply as drinking water.

(*a*) One source of water for supply to households is a lake that contains water that is slightly acidic. During water treatment this acidity is neutralised by adding base.

(*i*) What is an acid?

(*ii*) Define pH.

(*iii*) Calculate the pH of a 0.02 M **HCl** solution correct to one decimal place.

(*iv*) Why should a household **not** be supplied with acidic water?

(*v*) Slaked lime (**$Ca(OH)_2$**) is the base usually added to acidic water to adjust its pH.
Does the pH of water increase or decrease when base is added to it? (24)

(*b*) Another water source is a river that contains water with a moderate amount of temporary hardness but this hardness is not removed during water treatment.

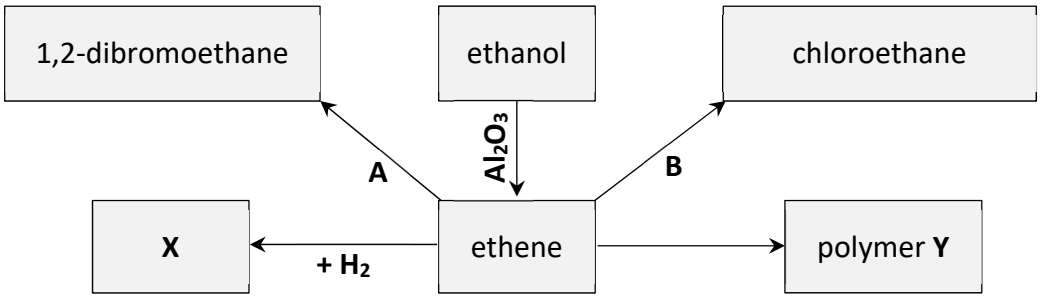
(*i*) How could you show, using soap flakes, that a water sample contains hardness?

(*ii*) Name a substance that causes *temporary* hardness in water.

(*iii*) Give one way that a householder could soften this hard water.

(*iv*) Give one advantage and one disadvantage to a household of having a hard water supply. (26)

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



(*a*) (*i*) Name the homologous series to which ethene (**C_2H_4**) belongs.

(*ii*) Draw the structure of an ethene molecule showing all of its atoms and bonds.

(*iii*) Is the geometry around the carbon atoms in ethene planar or tetrahedral? (15)

(*b*) (*i*) Name the product **X** of the addition of **H_2** to ethene.

(*ii*) **A** and **B** are two other addition reactions of ethene.
Identify the substance added to ethene in each case. (12)

(*c*) Name the reaction type involved when ethanol is converted to ethene using heated **Al_2O_3**. (6)

(*d*) Name **Y** which is made by polymerising ethene. (6)

(*e*) Benzene, an <u>aromatic compound</u>, is unreactive with regard to addition reactions.

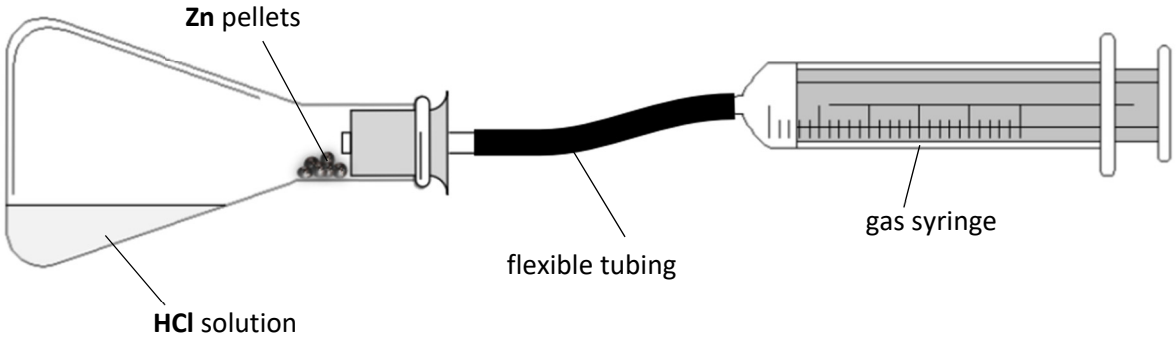
(*i*) Explain the underlined term.

(*ii*) Draw the structure of a benzene molecule. (11)

9. The apparatus shown below was used to investigate the rate of formation of hydrogen gas according to the following balanced equation.

$$\mathbf{Zn + 2HCl \rightarrow ZnCl_2 + H_2}$$

The reaction was started by bending the flexible tubing and standing the flask on its base so that the zinc pellets fell into the acid. A stop-watch was started at the same time. The volume of hydrogen gas collected was measured at intervals over a 12-minute period using a gas syringe.



A set of results obtained at room temperature in such an investigation is given in the table.

Time (minutes)	0	2	4	6	8	10	12
Volume $\mathbf{H_2}$ (cm^3)	0	32	50	62	69	72	72

(*a*) What is meant by the rate of a chemical reaction? (6)

(*b*) (*i*) Plot a graph (on graph paper) of volume of $\mathbf{H_2}$ *versus* time (*x*-axis).

(*ii*) Does the rate of this reaction increase or decrease with time? Give a reason for your answer. (21)

(*c*) From your graph find

(*i*) the total volume of hydrogen gas produced, measured at room temperature,

(*ii*) the time taken to produce half this volume of hydrogen,

(*iii*) the average rate of the reaction over the first 5 minutes (in cm^3 of $\mathbf{H_2}$ per minute at room temperature). (15)

(*d*) How would you expect the initial rate of this reaction to be affected by

(*i*) using the same volume of a more concentrated **HCl** solution,

(*ii*) using the same mass of powdered zinc instead of the pellets of zinc? (8)

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

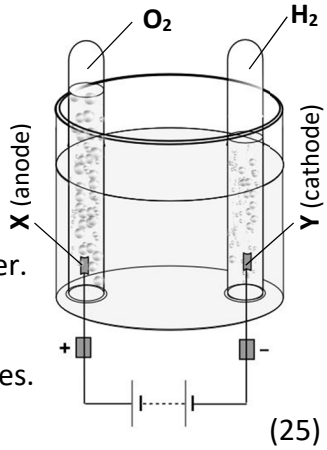
(*a*) The following words are omitted from the passage below.

neutral **Rutherford** **atomic** **positive**
Bohr **mass** **negative**

Write in your answerbook the omitted word corresponding to each of the numbers (**1** to **7**).

The number of protons in an atom is its **1** number and the sum of the protons and neutrons in its nucleus is its **2** number. The number of electrons in the electron cloud of a **3** atom is the same as the number of protons in its nucleus. It was **4** who discovered that an atom has a small dense **5** central nucleus and it was **6** who first described the arrangement of the electrons in energy levels in the electron cloud of an atom. In a chemical reaction an atom becomes charged if it loses one or more of its electrons or gains one or more additional electrons. If the atom gains one or more electrons it becomes a **7** ion. (25)

(*b*) The diagram shows how acidified water can be electrolysed using inert electrodes. The overall reaction that takes place during the electrolysis is:



$$H_2O_{(l)} \rightarrow H_{2\,(g)} + \tfrac{1}{2}O_{2\,(g)}$$

This is a redox reaction.

Define (*i*) oxidation, (*ii*) reduction, in terms of electron transfer.

(*iii*) What is the ratio, by volume, of H_2 to O_2 produced?

(*iv*) Identify a suitable material for use as the inert electrodes.

(*v*) At which electrode, **X** or **Y**, does oxidation take place? (25)

(*c*) AdBlue, a solution of urea (NH_2CONH_2) in water, is used in the exhaust systems of some diesel-powered vehicles to remove NO_2 from the hot exhaust flow by making use of the following reaction.

$$4NH_2CONH_2 + 6NO_2 \xrightarrow[400\ ^oC]{\text{catalyst}} 7N_2 + 8H_2O + 4CO_2$$

(*i*) What is a catalyst?

(*ii*) What is the mass of one mole of NH_2CONH_2?
There are 1,620 g of urea in a container of AdBlue.
How many moles of urea are there in the container?

(*iii*) How many moles of NO_2 gas react with **one** mole of urea in the reaction above?
What volume does this amount of NO_2 occupy, measured at s.t.p.? (25)

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

(*a*) Refer to page 79 of the *Formulae and Tables* booklet when answering this question.

In the periodic table of the elements, what term is used for the elements

(*i*) in the same vertical column,

(*ii*) in the same horizontal row?

(*iii*) Identify a metallic element whose atoms have the same number of main energy levels occupied by electrons as boron (**B**).

(*iv*) When Mendeleev published his first periodic table in 1869 the elements were arranged in order of atomic weight (or relative atomic mass).
How are the elements ordered in the modern periodic table?

(*v*) The element germanium (**Ge**) had not been discovered when Mendeleev published his first periodic table but he was able to predict its existence and its properties.
How did Mendeleev know what properties the undiscovered element germanium could be expected to have? (25)

(*b*) In seawater carbonic acid and carbonate ions react together according to the following equilibrium equation to form hydrogencarbonate ions.

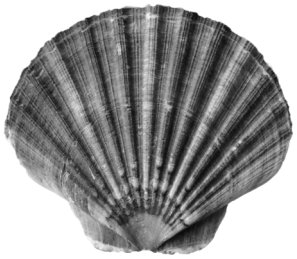
$$\mathbf{H_2CO_3}_{(aq)} + \mathbf{CO_3^{2-}}_{(aq)} \rightleftharpoons \mathbf{2HCO_3^-}_{(aq)}$$

(*i*) What is meant by a chemical equilibrium?

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

(*iii*) Supply the missing words in the following statement:
'If this equilibrium is disturbed by increasing the concentration of carbonic acid (**H_2CO_3**), then according to _____ principle, the concentration of the hydrogencarbonate ion (**HCO_3^-**) is observed to _____.'

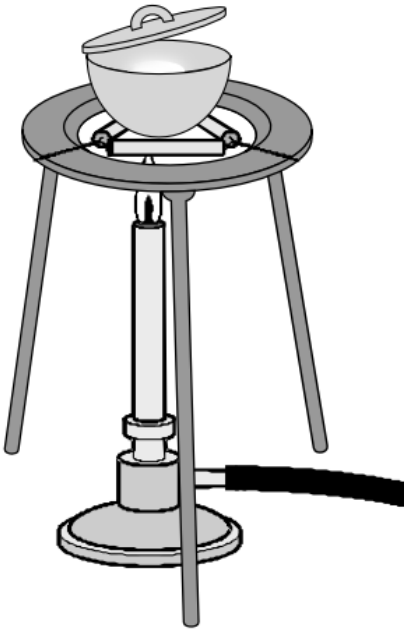
Marine shellfish and coral use carbonate ions (**CO_3^{2-}**) to make calcium carbonate (**$CaCO_3$**) shell. Human activity over the past 170 years or so, in particular burning fossil fuels, has resulted in a continuously increasing concentration of carbonic acid in seawater.



(*iv*) Use the equilibrium equation above and the principle referred to in (*iii*) to predict the effect of increasing the quantities of carbonic acid in seawater on shell-making by these creatures.
Explain your answer. (25)

This question continues on the next page.

(*c*) To prepare a sample of magnesium oxide, a small strip of magnesium ribbon was placed inside a crucible and heated strongly as shown in the diagram. The lid of the crucible was raised slightly several times during the heating process.



The magnesium ignited as it reacted in air and magnesium oxide was formed according to the word equation:

magnesium + oxygen gas $\rightarrow$ *magnesium oxide*

(*i*) Suggest a reason why the lid of the crucible was raised during the heating process.

(*ii*) Use the valencies of magnesium and oxygen to write the chemical formula of magnesium oxide.

(*iii*) Replace the words in the word equation above with chemical formulae and balance your equation.

(*iv*) Would you expect the mass of the crucible and its contents to increase, decrease or remain constant as the reaction proceeded?
Explain your answer. (25)

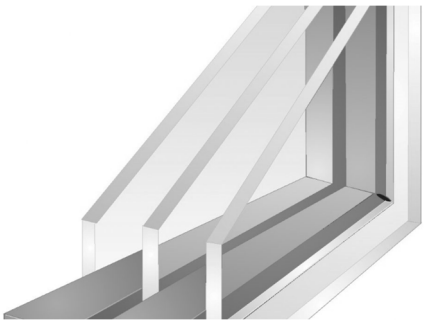
(*d*) Answer part **A** *or* part **B**.

A

Air is the source of several industrial gases. The three main products separated from liquid air by fractional distillation are **N_2**, **O_2** and **Ar**. When the liquid air, at a temperature below –196 °C, is allowed to warm up slowly, the component gases separate according to boiling point.

(*i*) Which of the three elements, nitrogen, oxygen or argon, is the most abundant in air?

(*ii*) Argon is used to fill the spaces between the sheets of glass in double and triple glazed windows. Give one major use for each of the other **two** elements, **N_2** and **O_2**, separated in the fractional distillation of liquid air.



(*iii*) Both **N_2** and **Ar** are chemically inert.
Explain the inertness of nitrogen gas.

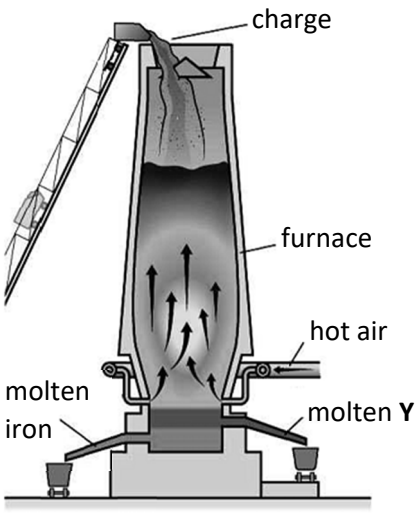
(*iv*) Nitrogen in air is essential to plants but they cannot make use of the gas itself. What term describes the conversion of **N_2** into compounds that can be used by plants?

(*v*) Ozone (**O_3**), that occurs in the stratosphere, is another form of the element oxygen.
Give a beneficial role of ozone in the stratosphere. (25)

or

B

The diagram shows a blast furnace used to extract iron, a transition element, from its ores by chemical reduction. The charge, a mixture of iron ore, limestone and a third substance, **X**, is added in at the top of the furnace. The molten iron collected at the base of the furnace is called pig iron and it is usually converted to steel.



(*i*) Give one general property of transition elements.

(*ii*) Identify **X** added in the charge to bring about the reduction of the iron ore and to act as a fuel for the furnace.

(*iii*) Calcium oxide obtained from the limestone reacts with impurities in the iron ore to make co-product **Y** that is collected at the base of the furnace.
What name is usually given to **Y**?
Give a use for **Y**.

(*iv*) Identify the main impurity in the pig iron whose concentration is reduced during steel making. (25)

There is no examination material on this page.

Image Q4(*c*) on page 5: from www.dailyecho.co.uk
File: www.dailyecho.co.uk/resources/images/1516156, accessed 01 September 2020

Image Q10(*c*) on page 11: from www.flickr.com
File: photos/opelblog/41946956472, accessed 15 June 2020, CC-BY-NC-ND-2.0

Image Q11(*b*) on page 12: from www.pixabay.com
File: sea-shell-clam-oceans-sea-shells-1162744, accessed 22 June 2020

Image Q11(*d*) on page 14: from https://www.turkington-windows.com
File: wp-content/uploads/2015/05/energy-efficientglazing.jpg, accessed 22 June 2020

Leaving Certificate – Ordinary Level

Chemistry

Tuesday, 22 June
Afternoon, 2:00 – 5:00