Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2023

CHEMISTRY – ORDINARY LEVEL

TUESDAY, 20 JUNE – AFTERNOON, 2:00 to 5:00

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400 MARKS

Answer any **eight** 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, Mg = 24, Ti = 48

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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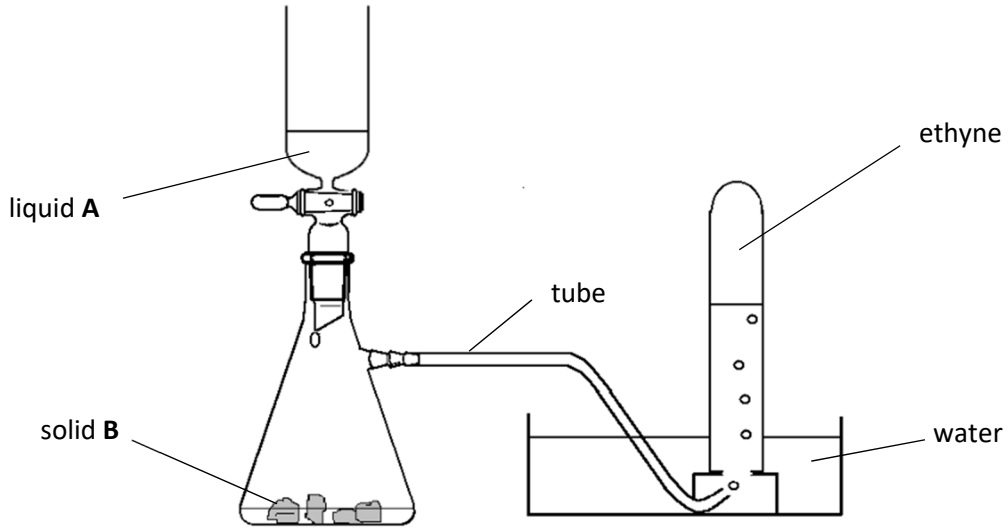
Section A

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

1. The apparatus shown in the diagram below can be used to make and collect the hydrocarbon gas ethyne (C_2H_2) in the school laboratory.



(*a*) Identify

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

(*ii*) solid **B**. (11)

(*b*) (*i*) Explain why ethyne can be collected over water.

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

(*c*) Ethyne is an <u>unsaturated</u> hydrocarbon.

(*i*) Draw the structure of the ethyne (C_2H_2) molecule showing all of its atoms and all of its bonds.

(*ii*) Explain the underlined term.

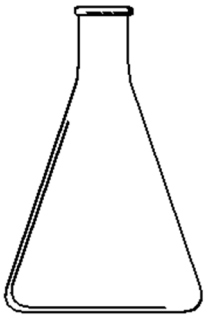
(*iii*) What colour change is observed when bromine solution is added to a test-tube of ethyne in a test for unsaturation? (18)

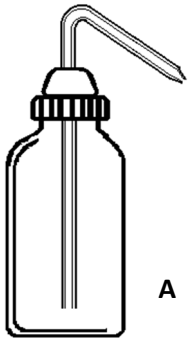
(*d*) (*i*) Describe how to carry out a combustion test on a sample of ethyne.

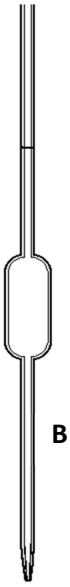
(*ii*) Describe the flame observed.

(*iii*) Give a major use for ethyne. (12)

2. A student titrated 25.0 cm^3 portions of a 0.05 M solution of sodium carbonate (**Na_2CO_3**) with a solution of hydrochloric acid (**HCl**) of unknown concentration. A burette was used to add the **HCl** to the **Na_2CO_3** solution in a conical flask until an indicator showed that the end point had been reached. This procedure was repeated a number of times.
Some pieces of apparatus used to carry out the titration are shown below.


conical flask


A


B

(*a*) The sodium carbonate solution is a standard solution.
Explain the underlined term. (5)

(*b*) (*i*) Identify the pieces of apparatus **A** and **B** above.
(*ii*) Give one use for **A** during the titration.
(*iii*) Describe how **B** was rinsed for use in the titration.
(*iv*) Why would a beaker be less suitable than the conical flask to hold the **Na_2CO_3** solution as the **HCl** was being added from the burette? (21)

(*c*) (*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)

(*d*) The balanced equation for the titration reaction is:

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

The volumes of **HCl** required to neutralise 25.0 cm^3 of the 0.05 M sodium carbonate solution are given in the table.

Rough titration	First accurate titration	Second accurate titration
23.1 cm^3	22.5 cm^3	22.4 cm^3

(*i*) What was the purpose of the rough titration?
(*ii*) Calculate the average volume of **HCl** required to neutralise the **Na_2CO_3**.
(*iii*) Calculate the concentration, in moles per litre, of the **HCl** solution. (15)

3. The water in a river estuary is a mixture of seawater and freshwater. In 2022 the quality of the water in Irish estuaries was in decline as reported by the Environmental Protection Agency. Increasing concentrations of nitrate ion in the estuary waters are the main issue.

The quality of the water from an Irish estuary was analysed in a school laboratory.

(*a*) (*i*) With the aid of a labelled diagram, describe how the concentration of suspended solids in a sample of this water could have been measured.

(*ii*) Describe how the concentration of dissolved solids could then have been determined.

It was found that 500 cm^3 of the water contained 0.04 g of suspended solids.

Express this concentration in

(*iii*) g per litre,

(*iv*) mg per litre (p.p.m.). (26)

(*b*) The estuary water was tested for the presence of chloride ions, nitrate ions and sodium ions.

Ion	Formula	Test
Chloride ion	$\mathbf{Cl^-}$	Add $\mathbf{AgNO_3}$ solution to a sample of estuary water in a test-tube
Nitrate ion	$\mathbf{NO_3^-}$	Add $\mathbf{FeSO_4}$ solution to a sample of estuary water in a test-tube and then add concentrated $\mathbf{H_2SO_4}$ slowly down the side of the test-tube, giving two layers
Sodium ion	$\mathbf{Na^+}$	Carry out a flame test on the dissolved solids obtained from the estuary water

(*i*) Identify which of the ions in the first column of the table above are anions.

(*ii*) Name the reagent $\mathbf{AgNO_3}$ used in the test for the chloride ion.

(*iii*) What test result confirms the presence of the chloride ion?

(*iv*) In the nitrate test a positive result is the formation of a coloured ring between the two layers in the test-tube. What colour is this ring?

(*v*) What colour flame indicates the presence of sodium ions? (24)

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*) What term is used to describe atoms of the same element that have different numbers of neutrons?

(*b*) Draw a dot and cross diagram to show the covalent bonding in a molecule of hydrogen ($\mathbf{H_2}$).

(*c*) In your answerbook write the words required to complete the following statement about alpha particles.

'An alpha particle released by a radioactive nucleus consists of two _____ and _____ neutrons.'

(*d*) State the relationship between the pressure and volume of a fixed mass of gas at constant temperature according to Boyle's law.

(*e*) Define electronegativity.

(*f*) The major ingredient in oil of orange is limonene ($\mathbf{C_{10}H_{16}}$). There are 0.003 moles of limonene in a bar of orange-flavoured chocolate.
Find the mass of limonene in the bar of chocolate.

(*g*) What is a bomb calorimeter used to measure?

(*h*) Burning coal is an <u>exothermic reaction</u>.
Explain the underlined term.

(*i*) Name the semi-solid organic by-product of sewage treatment, collected in settlement tanks, and removed periodically for use as a soil conditioner and fertiliser.

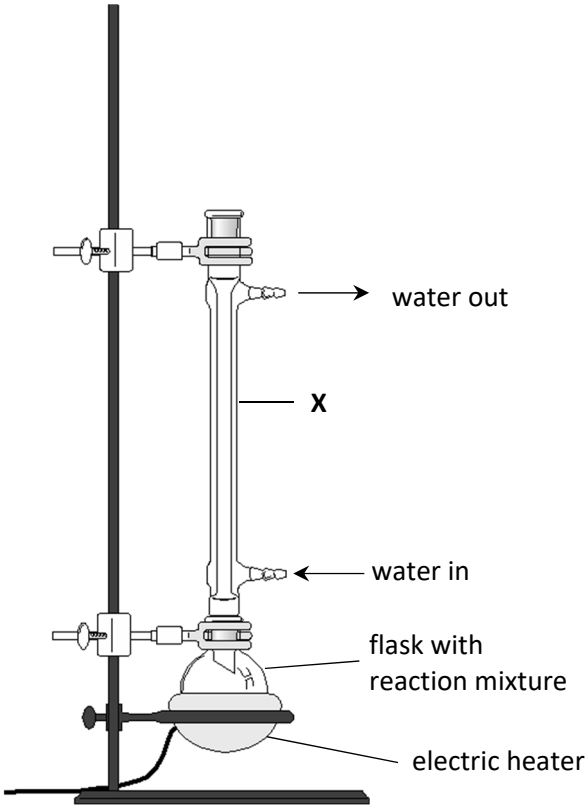
(*j*) Titanium dioxide ($\mathbf{TiO_2}$) is a white pigment used nowadays in cosmetics to replace the toxic white pigment containing lead that was used traditionally.
Find the percentage by mass of titanium in titanium dioxide.

This question continues on the next page.

(*k*) The diagram shows one of the stages of soap-making. The flask contains coconut oil, sodium hydroxide, ethanol and a few anti-bumping granules.

(*i*) Name the piece of apparatus labelled **X**.

(*ii*) What name is given to the process of heating a reaction mixture as shown?



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

A Why would the presence of carbon monoxide (**CO**) in the atmosphere be undesirable?

or

B Why must lead bromide (**$PbBr_2$**) salt be molten when electrolysing it into its constituent elements using inert electrodes?

5. Refer to page 79 of the *Formulae and Tables* booklet when answering this question.
A Russian scientist called Dmitri Mendeleev devised the first periodic table of the elements in 1869.

(*a*) (*i*) Define an element.

(*ii*) How did Mendeleev arrange the elements in his periodic table?

(*iii*) Give one difference between Mendeleev's table and the modern periodic table. (18)

(*b*) (*i*) Define atomic number.

(*ii*) What is the atomic number of lithium?

(*iii*) How many neutrons are there in an atom of $^{7}_{3}\mathbf{Li}$?

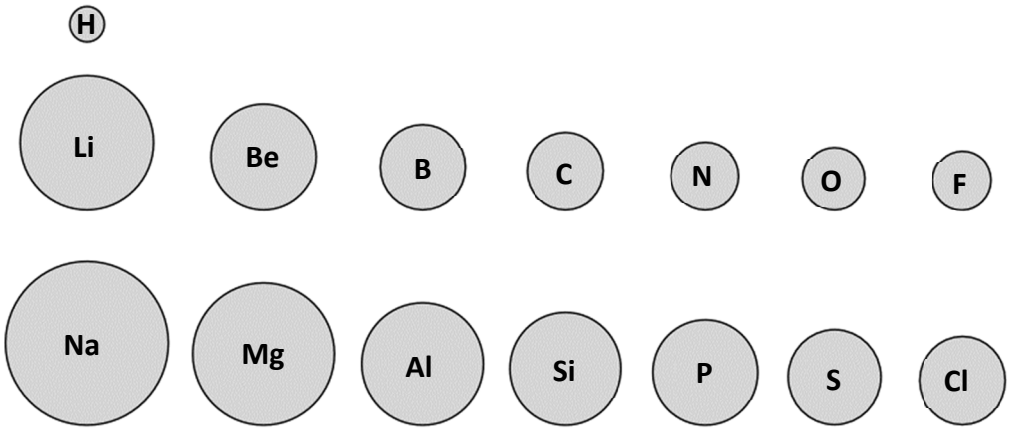
Write down the arrangement of electrons in the main energy levels

(*iv*) in an atom of lithium,

(*v*) in an atom of neon.

(*vi*) Refer to these arrangements of electrons to explain which element, lithium or neon, is more chemically reactive. (24)

(*c*) Atomic radius decreases across a period of the periodic table and increases down a group, as shown in the diagram below, of the relative sizes of the atoms of some elements.



(*i*) Give one reason why the atomic radius of sodium from Group 1 is larger than that of lithium from the same group.

(*ii*) Explain the decrease in atomic radius across the elements **Li** to **F** of the second period. (8)

6. (*a*) Methane is a greenhouse gas. Its increasing concentration in the atmosphere is a concern. Satellites showed that considerable quantities of methane were leaked into the atmosphere at oil and gas fields and from gas pipelines all over the world in 2022.

(*i*) Identify a significant source of methane **not** associated with the oil and gas industry.

(*ii*) Write the chemical formula for methane.

(*iii*) Methane is a hydrocarbon. Explain the underlined term. (14)

(*b*) Natural gas is a mixture of methane and smaller quantities of ethane, propane and butane. Tiny quantities of sulfur-containing mercaptans are usually added to natural gas before supplying it to its users.

(*i*) Give a major use for natural gas.

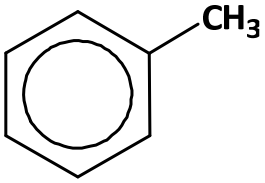
(*ii*) To which homologous series do methane, ethane, propane and butane belong?

(*iii*) Describe the geometry around the carbon atoms in a molecule of butane.

(*iv*) Why are mercaptans added to natural gas?

(*v*) Liquid petroleum gas (LPG) is another mixture of gases. What are the two main components of LPG? (24)

(*c*) (*i*) Name the aromatic compound whose structure is shown on the right.



(*ii*) State, giving a reason, whether methane is categorised as aromatic or aliphatic. (12)

7. (*a*) Define (*i*) an acid, (*ii*) a base. (8)

(*b*) Consider the neutralisation reaction between hydrochloric acid and potassium hydroxide.

(*i*) Copy and complete the following word equation for this type of reaction in your answerbook.

acid + *base* → *salt* + _____

(*ii*) Replace the words in the word equation with the chemical formulae for hydrochloric acid, potassium hydroxide and the products of their reaction to give a balanced equation. (9)

(*c*) (*i*) Give an example of a base, other than potassium hydroxide, used in the home or garden.

(*ii*) What use is made of this base in the home or garden? (9)

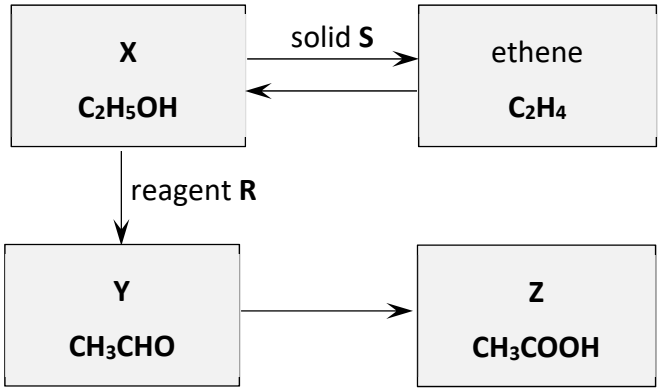
(*d*) (*i*) Define pH.

(*ii*) Calculate the pH of a 0.004 M **HNO_3** solution, correct to one decimal place.

(*iii*) How could you measure the pH of a solution?

(*iv*) What pH value would you expect to record if you measured the pH of deionised water? (24)

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



(*a*) (*i*) Give the systematic IUPAC names for **X**, **Y** and **Z**.

(*ii*) Give a use for **Z** in the food industry. (12)

(*b*) (*i*) Draw the structure of a molecule of **X** showing all of its atoms and all of its bonds.

Circle the group of atoms in your structure that makes **X** very soluble in water.

(*ii*) Explain why **X** dissolves easily in water. (12)

(*c*) (*i*) Ethene is formed when the vapour of **X** is passed over a heated white solid **S**. Identify the solid **S**.

(*ii*) Identify an oxidising reagent **R** that can be used to convert **X** to **Y**.

(*iii*) Describe what would be observed if a few drops of Fehling's reagent were added to about 0.5 cm^3 of **Y** in a test-tube which was then heated gently. (15)

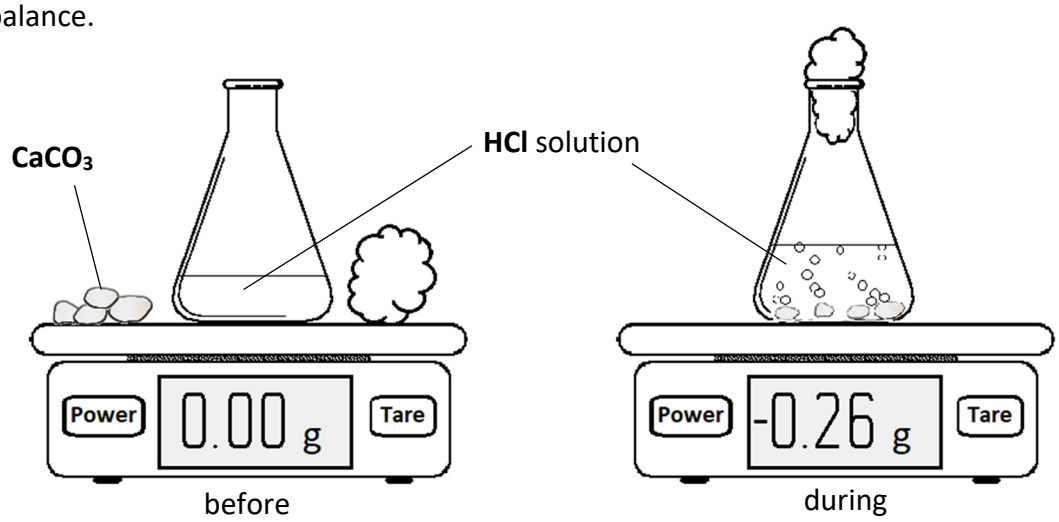
(*d*) (*i*) Classify the conversion of ethene to **X** as a substitution reaction or as an addition reaction.

(*ii*) Identify the organic reactant and the organic product of the elimination reaction in the scheme above. (11)

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

$$2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$$

A mass balance was zeroed with a few lumps of solid calcium carbonate, a flask containing excess hydrochloric acid at room temperature, and a cotton wool plug, standing on it.
A stopwatch was started when the calcium carbonate was added to the acid and the cotton-wool plug placed in the mouth of the flask. The mass of carbon dioxide gas produced and lost from the flask was measured at one-minute intervals over an 8-minute period using the balance.



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

Time (minutes)	0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
Mass CO_2 (grams)	0	0.26	0.41	0.50	0.56	0.59	0.60	0.60	0.60

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

(*b*) (*i*) Plot a graph (on graph paper) of the mass of CO_2 produced *versus* time (*x*-axis).
(*ii*) Does the rate of this reaction increase or decrease with time?
Give a reason for your answer. (21)

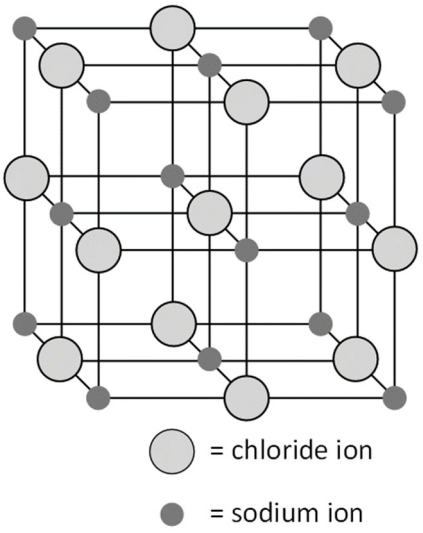
(*c*) From your graph find
(*i*) the time taken until the reaction was complete,
(*ii*) the time taken for 0.30 g of CO_2 to be produced and lost from the flask,
(*iii*) the mass of CO_2 produced over the first 2.5 minutes. (15)

(*d*) How would you expect the initial rate of this reaction to be affected if the procedure above was repeated exactly as before but this time using the same mass of $CaCO_3$ broken into smaller lumps? Justify your answer. (8)

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

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

The diagram shows the arrangement of sodium ions and chloride ions in an **NaCl** crystal with a chloride ion at its centre.



(*i*) How does a sodium atom become a sodium ion?

(*ii*) How does a chlorine atom become a chloride ion?

(*iii*) What is the maximum number of sodium ions that can surround (as its nearest neighbours) a chloride ion in the crystal?

(*iv*) What holds the ions together in the **NaCl** crystal structure?

(*v*) Give **two** properties of sodium chloride associated with its crystal structure. (25)

(*b*) Consider the following balanced equation for the redox reaction that takes place when a piece of magnesium ribbon is placed into a solution of copper(II) sulfate.

$$\mathbf{Mg + CuSO_4 \rightarrow MgSO_4 + Cu}$$

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

(*iii*) How many electrons are transferred for each copper atom formed in the reaction above?

(*iv*) Which is the reducing agent in the reaction, **Mg** or $\mathbf{CuSO_4}$?

(*v*) State one observation that would confirm that the reaction above occurs when magnesium is added to a copper(II) sulfate solution.

(*vi*) Would you expect a reaction to occur if a copper rod were to be dipped into a solution of $\mathbf{MgSO_4}$? Explain your answer. (25)

(*c*) When magnesium metal granules react in nitrogen gas, magnesium nitride, a yellow-green solid, is formed according to the following balanced equation.

$$\mathbf{3Mg + N_2 \rightarrow Mg_3N_2}$$

In a demonstration it was found that 0.6 moles of magnesium metal were completely converted to magnesium nitride.

(*i*) Magnesium nitride is a good catalyst for some reactions. What is a catalyst?

(*ii*) Find the number of atoms in 0.6 moles of magnesium.

(*iii*) How many moles of nitrogen gas reacted with 0.6 moles of magnesium?

(*iv*) Calculate the volume of this quantity of nitrogen gas, in litres measured at s.t.p.

(*v*) What is the mass of one mole of magnesium nitride ($\mathbf{Mg_3N_2}$)?

(*vi*) Find the mass of $\mathbf{Mg_3N_2}$ produced from 0.6 moles of magnesium. (25)

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

(*a*) Uisce Éireann treats 1.7 billion litres of water from lakes, rivers, wells and springs daily to make it safe for drinking and other uses. The typical steps of the process are given in the table below. The whole process takes 2 to 3 days to complete.

Drinking Water Treatment Process	
1	**Taking water from source and screening out large solids**
2	**Storage with some settlement/sedimentation**
3	**Flocculation**
4	**More settlement/sedimentation**
5	**Filtration**
6	**Disinfection**
7	**Fluoridation**
8	**pH adjustment**
9	**Testing, storage and distribution**

(*i*) What happens in the water during the flocculation step?

(*ii*) In a water treatment plant, through what material is water usually filtered after settlement and sedimentation?

(*iii*) Why is a drinking water supply disinfected?

How can this be done?

(*iv*) Why is the water fluoridated before being distributed to the users?

(*v*) What problem could arise if the pH of an acidic water supply was not adjusted before distribution?

(*vi*) Testing showed that the water from a particular source contained dissolved calcium hydrogencarbonate.

What information does this result give about the water? (25)

(*b*) The Haber process for manufacturing ammonia involves a reversible reaction between nitrogen and hydrogen, establishing a chemical equilibrium according to the following balanced equation.

$$\mathbf{N_2}_{(g)} + \mathbf{3H_2}_{(g)} \rightleftharpoons \mathbf{2NH_3}_{(g)}$$

(*i*) Explain the underlined terms.

(*ii*) Write the equilibrium constant ($\boldsymbol{K}_c$) expression for this reaction.

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

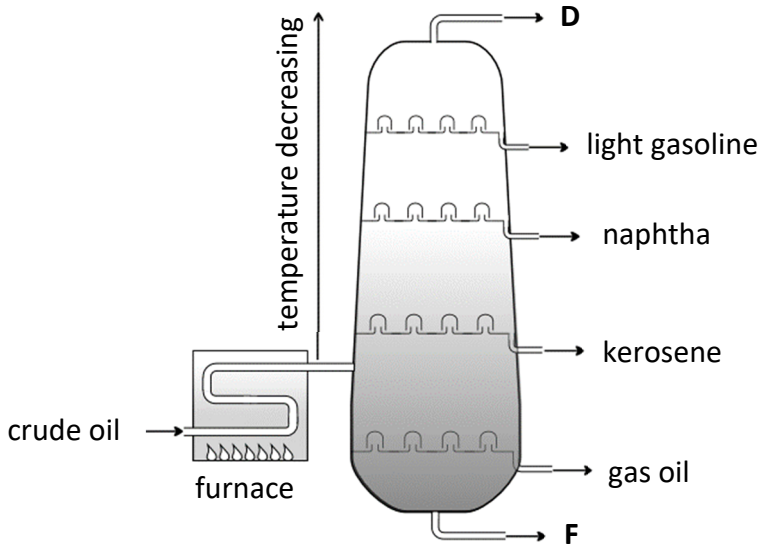
(*iv*) Why is it **not** advisable to carry out the Haber process at very high pressures even though high pressures favour ammonia production?

(*v*) Why is the Haber process carried out at temperatures of about 400 – 500 °C even though low temperatures favour ammonia production? (25)

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

high **residue** **small** **kerosene**
low **refinery gas** **large**

Refer to the diagram and write in your answerbook the omitted term corresponding to each of the letters **A** to **G**.



In oil refining, fractional distillation is used to separate the hydrocarbons in crude oil into useful fractions, e.g. __A__ is used as a fuel for jet aircraft. The hydrocarbons in the crude oil are separated in the fractionating column according to their boiling points and their molecular sizes. A hydrocarbon that has a __B__ boiling point rises higher up the column than a hydrocarbon that has a __C__ boiling point. The fraction collected at the top of the column is called __D__ and it consists of __E__ hydrocarbon molecules. The bottom fraction collected at the base of the column is called __F__ and it is made up of __G__ hydrocarbon molecules.

(25)

This question continues on the next page.

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

A

Oxygen is the most reactive gas in clean air. Nitrogen is one of the chemically inert gases in air. Industrially, oxygen and nitrogen are separated from one another and from the other gases by liquefaction of air followed by its fractional distillation.

(*i*) State one use of oxygen.

(*ii*) State one use for nitrogen based on its inertness.

(*iii*) How is the inertness of nitrogen explained by the structure of its molecules?

(*iv*) How abundant is nitrogen in the air?

(*v*) Explain the term nitrogen fixation.

(*vi*) Oxides of nitrogen can cause atmospheric pollution.
Explain the underlined term. (25)

or

B

Copper (**Cu**), gold (**Au**), iron (**Fe**) and lead (**Pb**) are examples of transition elements. All four elements are used in roofing, some structurally, others for decoration, some for both purposes.

copper

gold

iron

lead

(*i*) State **two** general properties of transition elements.

(*ii*) What is corrosion of metals?

(*iii*) Iron corrodes more easily than copper, gold, or lead.
Suggest a reason for this.

(*iv*) How does galvanising protect iron from corroding?

(*v*) What is steel? (25)

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Leaving Certificate – Ordinary Level

Chemistry

Tuesday, 20 June
Afternoon, 2:00 – 5:00