LEAVING CERTIFICATE EXAMINATION, 1988

CHEMISTRY—HIGHER LEVEL

Question 1 and **five** other questions must be answered. These five *must* include question 2 or question 3 but may include *both* question 2 and question 3.
All the questions carry the same number of marks.

Relative atomic masses: H = 1, C = 12, N = 14, O = 16, S = 32, K = 39, Ca = 40, Fe = 56, Ag = 108
Gas constant (R) = 8·3 N m K^{-1} mol^{-1}
Molar volume at S.T.P. = 22·4 dm^3

1. Answer *eleven* of the following items (*a*), (*b*), (*c*), etc. All items carry the same marks. *Keep your answers short.*

(*a*) Give an example of (i) an ionic crystal, (ii) a covalent crystal.

(*b*) Write an equation for the reaction that takes place when calcium nitrate is heated strongly.

(*c*) How many moles of carbonate ions (CO_3^{2-}) are present in 2·76 grams of potassium carbonate (K_2CO_3)?

(*d*) Which species are acting as bases in the reaction?

$$C_2H_5NH_2 + H_2O \rightleftharpoons C_2H_5NH_3^+ + OH^-$$

(*e*) Predict the possible shapes of molecules of hydrides of general formula XH_2.

(*f*) Give the name and structural formula of the compound formed when calcium dicarbide reacts with water.

(*g*) Define the electronegativity of an element.

(*h*) How would you confirm the presence of iodide ions in aqueous solution?

(*i*) Calculate the pH of a 0·01 mol dm^{-3} solution of sodium hydroxide.

(*j*) Name (i) the fuel, (ii) the electrolyte, used in a fuel cell.

(*k*) Write the structural formula for phenylethene. What is the common name for this compound?

(*l*) Draw an energy profile diagram for an exothermic reaction. Indicate on the diagram the activation energy of the forward reaction.

(*m*) What is meant by the eutrophication of water?

(*n*) Name a polymer with the linkages $-\overset{\overset{O}{\|}}{C}-O-$

(*o*) What mass of silver(I) ions (Ag^+) will be discharged by the same quantity of electricity as will discharge 1·05 grams of iron(II) ions (Fe^{2+})?

(11 × 6)

2. From a bucket of spring water, containing dissolved calcium chloride and calcium hydrogencarbonate, 500 cm^3 of the water were accurately measured into a beaker and then boiled for about thirty minutes. When cool, the water from the beaker was filtered into a 500 cm^3 volumetric flask. Deionised water was then poured through the filter paper into the flask and finally the flask was made up carefully to the mark, again using deionised water. The water from the volumetric flask was then titrated in 100 cm^3 volumes with a 0·01 mol dm^{-3} solution of EDTA. The mean titration reading was 6·0 cm^3. When the measurement was repeated using 100 cm^3 volumes of the unboiled water from the bucket, the mean titration reading was 19·0 cm^3.

(i) Give the full name of EDTA. Suggest a suitable container for storing EDTA solutions. (9)

(ii) Name the indicator you would use for the titration and state the colour change at the end point. (9)

(iii) In order to ensure an accurate end point, a little of another solution must be added to the water. What type of solution is it and what purpose does it serve? (9)

(iv) Write an equation for the reaction that took place when the water was boiled. (9)

(v) Explain why it was necessary (*a*) to bring the volume back to 500 cm^3, (*b*) to use deionised water for this purpose. Why was deionised water poured through the filter paper into the volumetric flask? (12)

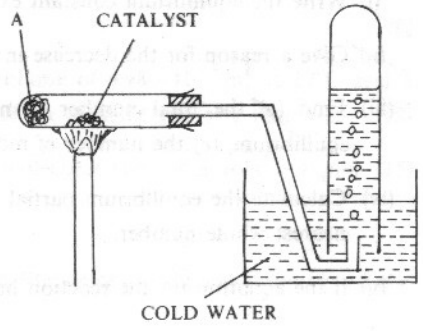
(vi) Using H_2X^{2-} to represent the EDTA anion the titration reaction may be represented

$$H_2X^{2-} + Ca^{2+} \rightarrow CaX^{2-} + 2H^+$$

Calculate the total hardness of the water in the bucket expressed as parts per million (p.p.m.) of calcium carbonate. Calculate also the hardness that was due to the presence of the calcium hydrogencarbonate. (18)

3. Oil refining separates crude oil into a number of different fractions. Liquid paraffin is obtained from one of these fractions.

In the laboratory experiment shown in the diagram, glass wool soaked in liquid paraffin is placed in the test tube at A and the catalyst consists of steel wool or pieces of porcelain. The catalyst is heated, gently at first and then strongly and, after allowing time for air to escape, several test tubes of a colourless gas (or mixture of gases) are collected. The gas (or mixture) is found to be flammable and to decolourise a solution of bromine in 1,1,1 – trichloro-ethane.



(i) What term is used to describe the process illustrated in this experiment? Comment on the industrial importance of this process. (9)

(ii) What is the function of the glass wool? In setting up the apparatus, why is it better to put the liquid paraffin into the test tube *before* the glass wool? (9)

(iii) When the heat is removed at the end of the experiment, a certain precaution is taken. What is this precaution and why is it necessary? (6)

(iv) Mention another possible hazard in this experiment, stating its cause and the safety precautions that should be taken. (9)

(v) Why would the first test tube of gas collected contain less unsaturated materials than those test tubes of gas collected at a later stage? (6)

(vi) Give the name and formula of a gas that could be responsible for the decolourising of the bromine solution. Write an equation for the reaction and name the product. (12)

(vii) If one of the straight-chain hydrocarbons in liquid paraffin, of molecular formula $C_{12}H_{26}$, were subjected to the process described in the experiment, suggest *three* possible products of the reaction giving the name and structural formula in each case. (15)

4. Define (i) heat of combustion, (ii) heat of formation, (iii) bond energy. (18)

The equation for the combustion of butane is

$$C_4H_{10(g)} + 6\tfrac{1}{2}O_{2(g)} \rightarrow 4CO_{2(g)} + 5H_2O_{(l)}$$

On complete combustion, 280 cm^3 of butane (at S.T.P.) produced 36 kJ of heat. Calculate (i) the heat of combustion, (ii) the kilogram calorific value, of butane. (12)

If the heats of formation of $H_2O_{(l)}$ and $CO_{2(g)}$ are -286 kJ mol^{-1} and -393 kJ mol^{-1} respectively, calculate the standard heat of formation of butane. (12)

Given the following data, where E stands for the average bond energy, find the average bond energy of the C—C bonds in butane.

$$E(C—H) = 412 \text{ kJ mol}^{-1}$$

$$E(H—H) = 436 \text{ kJ mol}^{-1}$$

$$C_{(s)} \rightarrow C_{(g)} \quad \Delta H = 715 \text{ kJ mol}^{-1}$$ (18)

There is another compound which is a structural isomer of butane. Write the structural formula of this isomer and give its systematic (IUPAC) name. (6)

5. When 12·8 grams of sulphur dioxide and 3·2 grams of oxygen were mixed together in a closed vessel at a certain temperature, the initial pressure was exactly 1 atmosphere but, when equilibrium had been reached at the same temperature, the pressure in the vessel had decreased to 0·8 atmosphere. The reaction may be represented

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

(i) Write the equilibrium constant expression for the reaction in terms of partial pressures. (6)

(ii) Give a reason for the decrease in pressure. (6)

(iii) Find (*a*) the total number of moles present initially, (*b*) the total number of moles present at equilibrium, (*c*) the number of moles of each gas present at equilibrium. (15)

(iv) Calculate the equilibrium partial pressures of the three gases and find the value of K_p correct to the nearest whole number. (15)

(v) If the equation for the reaction had been written in the form

$$SO_{2(g)} + \tfrac{1}{2}O_{2(g)} \rightleftharpoons SO_{3(g)}$$

what change, if any, would there have been in the value of K_p? (9)

(vi) Comment briefly on the industrial importance of the above reaction and state the conditions under which it is usually carried out.
What very harmful form of air pollution results from the reaction of sulphur dioxide with atmospheric moisture? (15)

6. There are normally two stages in the production of aluminium from its ore. In the first stage pure alumina is obtained, and in the second stage aluminium is extracted from the alumina by electrolysis.

(i) Name the main ore of aluminium. (6)

(ii) Outline the steps involved in the production of pure alumina from the ore named in (i). (24)

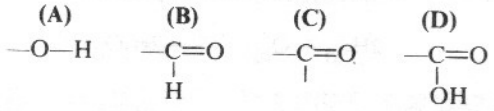
(iii) What property of alumina makes the electrolysis of the pure compound very difficult? How is the difficulty overcome? (12)

(iv) The anodes used in the electrolysis have to be replaced at intervals. What chemical reaction is responsible for this? (9)

(v) Describe, with the aid of a diagram, how you would anodise a piece of aluminium. What change takes place in the aluminium and what is the benefit of the anodising process? (15)

7. Explain the terms *functional group, homologous series, condensation reaction* in organic chemistry. (18)

Study the functional groups **A, B, C, D,** and answer the questions that follow.



(**Note:** the free bonds in **B** and **D** can be with hydrogen atoms or alkyl groups; those in **A** and **C** are restricted to alkyl groups.)

(i) In the case of each of the functional groups, name the homologous series in which it is found. For each homologous series give the name and structural formula of the C-3 homologue (i.e. the member of the series containing three carbon atoms). (24)

(ii) State the reagents and conditions necessary to convert the C-3 compound with functional group **A** to that with functional group **B** *or* **C**. (9)

(iii) Write an equation for the condensation reaction with 2,4-dinitrophenylhydrazine of *either* the compound with functional group **B** *or* the compound with functional group **C** named in (i) above. Name the organic product of the reaction and give its structural formula. (15)

8. State Boyle's Law. Define relative molecular mass (M_r). (12)

What is understood by an ideal gas? Give two ways in which real gases depart from ideal behaviour. Under what conditions of temperature and pressure would a real gas depart most from ideal behaviour? (15)

Write down the equation of state for an ideal gas. (6)

A mass of 5·6 grams of a gaseous diatomic element occupies a volume of $4{\cdot}98 \times 10^{-3}\ m^3$ at 27°C and a pressure of $1{\cdot}0 \times 10^5\ N\,m^{-2}$ (Pa). Find the relative molecular mass of the element and give its name. (18)

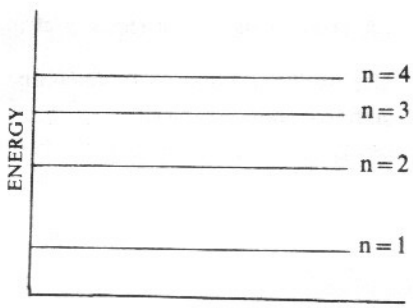
Outline an experimental procedure used to determine the relative molecular mass of a volatile liquid. (15)

9. (*a*) Discuss briefly the contributions of Dobereiner, Newlands and Mendeleef to the development of the Periodic Table. (18)

State *two* differences between Mendeleef's form, and the modern form, of the Periodic Table. (Refer to Mathematics Tables, page 44). (6)

(*b*) Indicate briefly how the presence of energy levels in atoms may be used to explain the characteristic emission spectra of elements. (12)

The energy-level diagram shows the first four energy levels.



(i) What is the maximum number of electrons that can be accommodated at the third (n = 3) energy level? (3)

(ii) Why is the arrangement of electrons in energy levels for the ground state configuration of potassium 2, 8, 8, 1 and not 2, 8, 9? (6)

(*c*) Write the electronic configuration (s, p) for atoms of nitrogen, phosphorus and sulphur. Account for the decrease in first ionisation energy (i) from nitrogen to phosphorus, (ii) from phosphorus to sulphur. (21)

10. Answer any *two* of the following.

(*a*) Define *catalyst*. (6)

The following reactions are both carried out at room temperature

$$2H_{2(g)} + O_{2(g)} \xrightarrow{Pt_{(s)}} 2H_2O_{(l)}$$

$$16H^+_{(aq)} + 2MnO_{4(aq)}^- + 5C_2O_{4(aq)}^{2-} \longrightarrow 10CO_{2(g)} + 2Mn^{2+}_{(aq)} + 8H_2O_{(l)}$$

(i) The first reaction is an example of heterogeneous catalysis. Explain what this means and use the reaction to illustrate the surface adsorption theory of catalysis. (15)

(ii) In the second reaction, the rate increases with addition of manganate(VII) solution. How would you verify this by experiment? Identify the species acting as a catalyst in this reaction and give the term usually used for this type of catalysis. (12)

(*b*) Explain the terms *strong* and *weak* as applied to acids and bases. (6)

The dissociation of an indicator(HIn) which is a weak acid may be represented

$$HIn \rightleftharpoons H^+ + In^-$$

How is the degree of dissociation affected (i) by the addition of a strong acid, (ii) by the addition of a strong base? Explain your reasoning. (12)

The following table shows the results of titrating 25·0 cm^3 volumes of 0·1 mol dm^{-3} ethanoic acid solution with a 0·1 mol dm^{-3} solution of sodium hydroxide using two different indicators.

Indicator	pH range	Volume of hydroxide solution
Methyl Red	4·2–6·3	22 cm^3
Phenolphthalein	8·3–10·0	25·0 cm^3

(i) Which is the correct volume of hydroxide solution? (3)

(ii) Explain why the colour change coincided with the end point of the titration for one indicator but not for the other indicator. (12)

(*c*) From the following list:

$$H_2O_2 \quad CaO \quad CO \quad NO_2 \quad Na_2O \quad Cu_2O \quad ZnO$$

identify the three compounds A, B, C, described below, writing equations for any reactions that are mentioned.

(i) A is a white solid, mainly ionic in character and slightly soluble in water forming a solution which gives a white precipitate when carbon dioxide is bubbled through it. (9)

(ii) B is a colourless gas, insoluble in water. It reduces iron ore to iron in the blast furnace. (9)

(iii) C is a white solid, insoluble in water. It reacts both with hydrochloric acid and with sodium hydroxide. (15)

(*d*) Define *reduction* in terms of change in oxidation number. (6)

Use oxidation numbers to determine whether or not each of the following is a redox reaction and, if so, state the species reduced.

$$S_2O_3^{2-} + 2HCl \rightarrow H_2O + SO_2 + S + 2Cl^-$$

$$2O_2^{2-} + 2H_2O \rightarrow 4OH^- + O_2$$

$$BiCl_4^- + H_2O \rightarrow BiOCl + 2HCl + Cl$$

(18)

Using oxidation numbers, or otherwise, balance the following equation:

$$Cr_2O_7^{2-} + Cl^- + H^+ \rightarrow Cr^{3+} + H_2O + Cl_2$$

(9)