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LEAVING CERTIFICATE EXAMINATION, 2000

CHEMISTRY — HIGHER LEVEL

TUESDAY, 20 JUNE — AFTERNOON 2.00 to 5.00

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.

Question 1 carries a total of 70 marks.
All other questions carry a total of 66 marks each.

Relative atomic masses: H = 1, C = 12, N = 14, O = 16, Al = 27,
K = 39, Ca = 40, Mn = 55, Fe = 56, Zn = 65.

Avogadro constant = 6×10^{23} mol^{-1}

Gas constant (R) = 8.3 J K^{-1} mol^{-1}

1. Answer *eleven* of the following items (*a*), (*b*), (*c*), etc. All items carry the same number of marks. However, one additional mark will be given to each of the first four items for which the highest marks are obtained.
Keep your answers short.

(*a*) Identify the atom or ion with the electronic configuration (i) $1s^2 2s^2$, (ii) $[1s^2 2s^2 2p^6]^{2-}$.

(*b*) What is meant by *polar covalent bonding*? Give an example.

(*c*) What mass of zinc would liberate 3 x 10^{22} molecules of hydrogen gas from excess dilute hydrochloric acid?

(*d*) Give the name and structural formula of the aromatic hydrocarbon of molecular formula C_7H_8.

(*e*) Write an equation for the reaction that takes place when lead(II) nitrate is heated strongly.

(*f*) State the shape of a molecule of (i) AsH_3, (ii) HCHO.

(*g*) Give *two* effects of increased temperature on the following reaction.

$$N_{2(g)} \quad + \quad 3H_{2(g)} \quad \rightleftharpoons \quad 2NH_{3(g)} \qquad \Delta H = -92 \text{ kJ}$$

(*h*) A bottle of potassium hydroxide solution was labelled 2.8% (w/v). What was the concentration of the solution in mol dm^{-3}?

(*i*) Give the name and structural formula of an ester which is a structural isomer of ethanoic acid (CH_3COOH).

(*j*) Draw an energy profile diagram for the neutralisation reaction between hydrochloric acid and sodium hydroxide solution.

(*k*) Give any *two* benefits of catalytic cracking.

(*l*) At what stage of sewage treatment (i) are most solids removed, (ii) are phosphate ions removed?

(*m*) State *two* advantages of fuel cells.

(*n*) The equation of state for an ideal gas is $PV = nRT$. Name two of the gas laws on which this equation is based.

(*o*) When 6.87 g of an oxide of manganese was reduced, 4.95 g of the metal was obtained. Find the empirical formula of the oxide. (70)

2. A sample of water, which contained both temporary and permanent hardness, was analysed in the school laboratory. The water was titrated in 50 cm^3 volumes against a 0.01 mol dm^{-3} solution of EDTA using a suitable indicator and the mean titre was found to be 12.2 cm^3. A 1 dm^3 volume of the sample was then boiled in a beaker for about thirty minutes. When it had cooled to room temperature, it was filtered and then the original volume was accurately restored using deionised water. When this water was titrated in 50 cm^3 volumes against the same EDTA solution, the mean titre was 5.5 cm^3.

(i) What is hard water? Explain the terms *temporary* and *permanent* hardness. (9)

(ii) Describe how you would accurately restore the boiled water to its original volume and explain why it is necessary to do so. Why is *deionised* water used? (15)

(iii) Name a suitable indicator and state the colour change at the end-point of the titration. Why is it necessary to use a buffer solution? (12)

(iv) Name *one* compound that could have been responsible for the temporary hardness, and *one* compound that could have been responsible for the permanent hardness in the water sample. Write an equation for the reaction that took place when the water was boiled. (12)

(v) Using H_2Y^{2-} to represent the EDTA anion and M^{2+} to represent the cation responsible for hardness, the titration reaction may be represented:

$$H_2Y^{2-} + M^{2+} \longrightarrow MY^{2-} + 2H^+$$

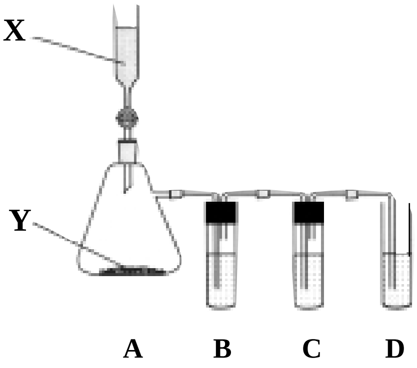
Calculate:

(*a*) the total hardness,

(*b*) the permanent hardness,

(*c*) the temporary hardness, of the water sample, expressing your answers in terms of parts per million (p.p.m.) of calcium carbonate. (18)

3. In the apparatus shown in the diagram, ethyne was prepared by the reaction between **X** and **Y** in the conical flask **(A)**. The ethyne was purified by bubbling it through the solution in **B**. The pure ethyne was converted to ethanal by passing it through the hot solution in **C**. The ethanal vapour was then reacted with 2,4-dinitrophenylhydrazine in **D**.



(i) Name **X** and **Y**. Write an equation for the reaction between **X** and **Y** in which ethyne is produced. (12)

(ii) The solution in **B**, which is used to purify the ethyne, consists of two compounds dissolved in water. Identify the two compounds and give the name and formula of one of the impurities removed. (12)

(iii) The solution in **C** also consists of two compounds dissolved in water. Name the two compounds. Suggest a suitable temperature for the reaction in which ethyne is converted to ethanal. (9)

(iv) When the ethanal passes into the solution of 2,4-dinitrophenylhydrazine in **D**, a solid is produced. Give the name and colour of the solid and write an equation for the reaction. What term is used to describe this type of reaction? (15)

(v) The solid produced in **D** was recrystallised and then its melting point was measured. Describe how you would carry out the recrystallisation. What information could be obtained from the result of the melting point measurement? (18)

4. State *Le Chatelier's principle.* (6)

The following experiment was carried out to find the equilibrium constant (K_c) for the reaction

$$CH_3COOH_{(l)} \quad + \quad C_2H_5OH_{(l)} \quad \rightleftharpoons \quad CH_3COOC_2H_{5(l)} \quad + \quad H_2O_{(l)}$$

A mixture of 7.20 g of ethanoic acid, 5.52 g of ethanol and 1 cm^3 of concentrated sulphuric acid was allowed to come to equilibrium in a sealed flask at 298 K. The equilibrium mixture was then transferred to a volumetric flask and made up accurately to the mark with deionised water. By titration, it was found that the total acid in the equilibrium mixture required 0.06 moles of sodium hydroxide for neutralisation. In a separate titration, it was found that 1 cm^3 of concentrated sulphuric acid required 0.02 moles of sodium hydroxide for neutralisation.

(i) Write the equilibrium constant (K_c) expression in terms of molar concentrations for the reaction. (6)

(ii) Name an indicator that would have been suitable for both titrations and state the colour change at the end-point. Explain clearly why the indicator you have named is suitable. (15)

(iii) How many moles of sodium hydroxide were required to neutralise the ethanoic acid present in the equilibrium mixture? Hence calculate the numbers of moles of ethanoic acid, ethanol, ethyl ethanoate and water in the equilibrium mixture and the value of K_c at 298 K. (21)

(iv) If the reaction were carried out without using sulphuric acid, what change, if any, would there have been in:

(*a*) the time taken to reach equilibrium, (*b*) the value of K_c.

Give a reason for your answer in each case. (12)

(v) What effect, if any, would changing the pressure have on the above reaction system at equilibrium? Give a reason for your answer. (6)

5. Answer this question by referring where necessary to the first thirty-six elements of the Periodic Table (Mathematics Tables p.44 and p.45).

(i) Define (a) isotopes, (b) relative atomic mass. Explain why the relative atomic masses of the naturally-occurring elements are not whole numbers. (18)

(ii) What do you understand by *energy level* in an atom?
How can the presence of energy levels in atoms be used to explain the characteristic emission spectra of elements? (15)

(iii) What is meant by the *first ionisation energy* of an element? (6)

In the third period (Na - Ar) of the Periodic Table, account for:

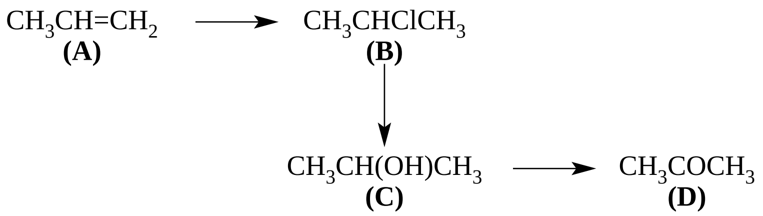
(*a*) the decrease in the first ionisation energy value from magnesium to aluminium,

(*b*) the increase in the first ionisation energy value from aluminium to phosphorus,

(*c*) the decrease in the first ionisation energy value from phosphorus to sulphur. (18)

(iv) The second ionisation energy is *always* greater than the first. What is the reason for this? Explain why the value of the second ionisation energy is much greater for potassium than it is for calcium. (9)

6. Study the following reaction scheme and answer the questions which follow.



(i) Give the systematic (IUPAC) names of **A**, **B**, **C**, **D**. (12)

(ii) To which homologous series does **A** belong? Give the name *and* structural formula of another member of this homologous series. (9)

(iii) Write an equation (a) for the reaction involved in converting **A** to **B**, (b) for the reaction involved in converting **B** to **C**. What term is used for the type of reaction involved in (b)? (9)

(iv) Distinguish clearly between primary and secondary alcohols. To which of these two classes does **C** belong? (9)

(v) Describe how **C** could be converted to **D** in the laboratory. (15)

(vi) Give the name of the compound formed when **A** reacts with bromine. Outline the mechanism of this reaction. (12)

7. As part of the study of reaction rates the following student experiment was carried out. Some granular manganese(IV) oxide was added, as catalyst, to 20 cm^3 of hydrogen peroxide solution and the oxygen produced was collected by displacement of water from an inverted burette. The reaction and a stopclock were started at exactly the same time and the total volume of oxygen was noted at one minute intervals. The reaction was carried out at room temperature and pressure and the results are given in the following table.

Time/minutes	0	1	2	3	4	5	6	7	8
Volume/cm^3	0	12.0	18.0	21.2	23.0	23.8	24.0	24.0	24.0

(i) Define (a) rate of reaction, (b) catalyst. (9)

The reaction described above is an example of heterogeneous catalysis. How does this type of catalysis differ from homogeneous catalysis? Give an example of homogeneous catalysis stating the reactant(s) and the catalyst. (12)

(ii) Explain how you would have started the reaction and the clock at exactly the same time. (6)

(iii) Plot, on graph paper, a graph of volume against time. (9)

(iv) Use the graph to find the instantaneous rate of the reaction after 3 minutes. (9)

(v) What change, if any, would there have been in the graph (a) if powdered manganese(IV) oxide had been used instead of granules, (b) if the reaction vessel had been surrounded by ice-water? Give a reason for your answer in each case. (12)

(vi) Calculate the total number of moles of oxygen produced in the student experiment. Find also the initial molar concentration of the hydrogen peroxide solution given that the equation for the reaction is

$$H_2O_{2(aq)} \longrightarrow H_2O_{(l)} + {}^{1}/{}_{2}O_{2(g)}$$

(Molar volume at room temperature and pressure = 24 dm^3) (9)

8. In the most important ores of aluminium and of iron, the metals are present as trivalent metal oxides. Other oxides are present as impurities. Aluminium is obtained from its oxide by electrolysis whereas reduction of the oxide of iron is brought about by a different method.

(i) Name a major ore of aluminium *and* a major ore of iron. (6)

(ii) Explain why electrolysis is used in the reduction of the oxide of aluminium but not in the reduction of the oxide of iron. What method is normally used to reduce iron oxide to iron? (12)

(iii) Name *one* oxide often found as an impurity in aluminium ore and *one* oxide often found as an impurity in iron ore. Outline the method used (a) to remove impurities from aluminium ore, (b) to remove impurities from iron ore. (18)

(iv) What mass of iron could be obtained from 4.5 tonnes of an ore that contains 80%, by mass, of the trivalent metal oxide (Fe_2O_3)? How many faradays of electricity would be required to produce the same mass of aluminium from its trivalent oxide (Al_2O_3)? (18)

(v) State, giving the reason, which of the two metals, iron or aluminium, is more resistant to corrosion. How can the resistance to corrosion of this metal be increased? (12)

9. (*a*) (i) Sulphuric acid is a <u>strong</u>, <u>dibasic</u> acid. Explain the underlined terms. (9)

(ii) The equation for the first dissociation of sulphuric acid in aqueous solution is

$$H_2SO_4 \quad + \quad H_2O \quad \rightleftharpoons \quad H_3O^+ \quad + \quad HSO_4^-$$

Indicate the conjugate pairs in the equation. Show, by means of an equation, that the conjugate base of sulphuric acid can act as an acid in aqueous solution. (9)

(*b*) A volume of 750 cm^3 of water was filtered through a filter paper of mass 0.70 g. After drying, the mass of the filter paper was found to have increased to 0.73 g. A volume of 50 cm^3 of the filtered water was gently evaporated to dryness in a beaker of mass 91.56 g. After cooling, the mass of the beaker was found to have increased to 91.58 g.

(i) What term is usually used to describe the particles removed from the water by filtration? Give the name *or* formula of a compound used to help in removing these particles in the purification of water for drinking. (6)

(ii) Express the concentration in p.p.m. (a) of the particles removed by filtration, (b) of the particles obtained by evaporation. (12)

(*c*) Define: pH; the ionic product of water (K_w); acid dissociation constant (K_a). (9)

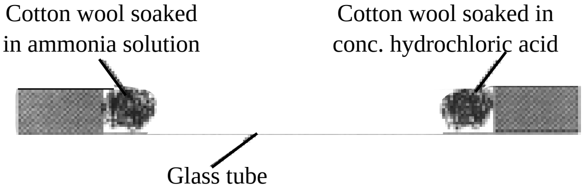
(i) If the value of K_a for methanoic acid is 1.9×10^{-4}, what is the concentration of a methanoic acid solution if the pH of the solution is 2.36? (6)

(ii) The pH of an aqueous solution at 25˚C is 12. What is the concentration of hydroxide ions in the solution? (At 25˚ C, $K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6}) (6)

(iii) The hydroxide ion concentration of pure water at 50 ºC is 2.35×10^{-7} mol dm^{-3}. Show that the pH of pure water at this temperature is less than 7. Though the pH of pure water is less than 7 at 50 ºC, explain why the water is *not* acidic at this temperature. (At 50 ºC, $K_w = 5.52 \times 10^{-14}$ mol^2 dm^{-6}) (9)

10. Answer any two of the following.

(*a*) State Graham's Law of Diffusion. (6)



The apparatus shown in the diagram was set up to compare the rates of diffusion of hydrogen chloride and ammonia. After a few minutes, a ring of white solid was seen forming in the glass tube.

(i) Write an equation for the reaction between hydrogen chloride and ammonia and name the white solid produced. (6)

(ii) Did the ring of white solid form nearer to the ammonia solution, nearer to the concentrated hydrochloric acid or half-way between the two? Explain your reasoning. (9)

(iii) 250 cm^3 of ammonia diffused through a porous plug in 25 seconds. 202 cm^3 of a gaseous hydrocarbon diffused through the same porous plug in 25 seconds under the same conditions. Determine the relative molecular mass of the hydrocarbon. Identify the hydrocarbon. (12)

(*b*) (i) An iodine solution may be prepared in the laboratory by the addition of potassium manganate(VII) to an acidified solution containing excess potassium iodide. The unbalanced equation for this reaction is given below. Show clearly where oxidation and reduction have taken place and then balance the equation.

$$MnO_4^- + I^- + H^+ \longrightarrow Mn^{2+} + H_2O + I_2$$ (15)

(ii) Why is an excess of potassium iodide used in preparing the iodine solution? What solution would you use to determine the concentration of an iodine solution? (12)

(iii) Describe a test for iodide ions in aqueous solution. (6)

(*c*) Define (i) heat of formation, (ii) bond energy. (12)

Use the following data (where E stands for bond energy) to calculate the bond energy of the carbon-to-carbon bond in ethene (C_2H_4).

E(H-H) = 436 kJ mol^{-1}
E(C-H) = 412 kJ mol^{-1}
$C_{(s)} \rightarrow C_{(g)}$ ΔH = 715 kJ mol^{-1}
Heat of formation of ethene : ΔH = 52 kJ mol^{-1} (15)

The bond energy of the carbon-to-carbon bond in ethane (C_2H_6) is 348 kJ mol^{-1}. Why is this value different from that obtained for ethene above? (6)

(*d*) (i) Explain the terms *nitrogen fixation* and *eutrophication.* (9)

What is the importance of nitrogen fixation? (3)

(ii) Lightning plays a part in one of the methods of natural nitrogen fixation. Outline how lightning in the atmosphere leads to the presence of nitrogen compounds in the soil. (12)

(iii) Give a brief description of the steps by which the application of nitrogenous fertilisers to agricultural land can lead to eutrophication of rivers and lakes. (9)