AN ROINN OIDEACHAIS AGUS EOLAÍOCHTA

LEAVING CERTIFICATE EXAMINATION, 2001

CHEMISTRY — HIGHER LEVEL

TUESDAY, 19 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, Na = 23, P = 31,
S = 32, Cl = 35.5

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

Molar volume at S.T.P = 22.4 dm^3

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

1 Faraday = 96 500 C

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*) How many (i) protons, (ii) neutrons are there in the selenium atom $^{79}_{34}\mathbf{Se}$?

(*b*) What type of crystals are formed by iodine?
What forces bind the crystal together?

(*c*) A sealed vessel contains 1.5 x 10^{21} atoms of helium gas at S.T.P. What is the volume of the vessel in cm^3?

(*d*) Write an equation for the reaction that takes place when bromine is added to an aqueous solution of potassium iodide.

(*e*) Write the structural formula of 2,2,4-trimethylpentane.

(*f*) State the possible shapes of molecules of the general formula $\mathbf{QX_2}$.

(*g*) Give the name <u>and</u> formula of a compound that could be responsible for causing permanent hardness in water.

(*h*) What, if anything, would you observe (i) when hydrogen is passed over heated zinc oxide, (ii) when hydrogen is passed over heated copper oxide?

(*i*) The bond energy values in kJ mol^{-1} of the C-Cl bond, the C-Br bond and the C-I bond are 338, 276 and 238 respectively. Suggest a reason for this trend.

(*j*) Distinguish between homogeneous and heterogeneous catalysis.

(*k*) An indicator changes colour in the pH range 7.6 – 9.2. For which types of acid-base titration would it be suitable?

(*l*) Some reactions of alkanes involve a free radical mechanism. What is a free radical?

(*m*) What is the name given to the energy change corresponding to the reaction represented by the equation:

$$\mathbf{X_{(g)} \rightarrow X^+_{(g)} + e^-}$$

(*n*) Describe a test to confirm the presence of chloride ions in an aqueous solution.

(*o*) The dissolved oxygen concentration of a sample of river water was found to be 8.0 p.p.m. Express the concentration of dissolved oxygen in mol dm^{-3}.

(70)

2. A sample of 2.51 g of hydrated sodium carbonate (washing soda) crystals, $Na_2CO_3.xH_2O$, was dissolved in deionised water and the solution made up to 250 cm^3 in a volumetric flask. The molarity of this solution was found by titrating 25.0 cm^3 portions of this solution against a 0.10 mol dm^{-3} solution of hydrochloric acid. The mean titration figure was found to be 20.0 cm^3.

The equation for the titration reaction is

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

(i) Describe the correct procedure for weighing and making up the solution from hydrated sodium carbonate crystals. (12)

(ii) Name a suitable indicator for the titration <u>and</u> state the colour change at the end point. (6)

(iii) Describe the correct procedure for washing the pipette and using it to measure the sodium carbonate solution. (9)

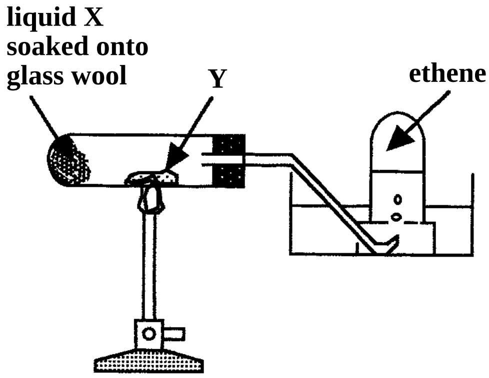
(iv) Assuming that the burette has been properly rinsed, state <u>three</u> other precautions that should be taken when using it in order to ensure an accurate measurement. (12)

(v) Calculate the concentration of the sodium carbonate in the washing soda solution in mol dm^{-3}? (9)

(vi) Calculate the value of x, the degree of hydration, of the crystals. (12)

(vii) Sodium carbonate crystals, $Na_2CO_3.xH_2O$, is not a primary standard but anhydrous sodium carbonate, Na_2CO_3, may be used as a primary standard. Why is this the case? (6)

3. A student used the apparatus shown in the diagram to prepare and collect a number of test tubes of ethene gas.



(i) Identify liquid **X** and solid **Y** and write an equation for the reaction that took place. (12)

(ii) The glass wool was used to hold liquid **X** at the bottom of the horizontal test tube. In setting up the apparatus, why was it preferable to put the liquid into the test tube before the glass wool? (6)

(iii) Why were the first few test tubes of gas collected not used? Why was the delivery tube removed from the water when heating was stopped? (6)

(iv) What did the student observe when a few drops of a solution of bromine in 1,1,1-trichloroethane was shaken in a test tube of ethene gas? What conclusion could be drawn from this observation? Name <u>and</u> give the structure of the product of this reaction. (12)

(v) What did the students observe when a few drops of an acidified potassium manganate(VII) solution was shaken in a test tube of ethene gas? One of the products of this reaction has the formula $(CH_2OH)_2$. Name this product and give a common use of it. (9)

(vi) The above apparatus can also be used to demonstrate *catalytic cracking* using liquid paraffin in place of liquid **X**. What is meant by *catalytic cracking*? In carrying out this experiment, what solid would you use in place of **Y**? (9)

(vii) When a sample of liquid paraffin was cracked, the mixture of products was found to contain a number of isomeric compounds of the formula C_4H_8. Draw the structure <u>and</u> give the IUPAC name of <u>two</u> of these compounds. (12)

4. Answer the following questions with reference to the Periodic Table, part of which is shown below.

1 **H**																	2 **He**
3	4											5	6	7 **N**	8	9	10
11 **Na**	12											13 **Al**	14	15 **P**	16	17 **Cl**	18
19	20	21	22	23	24 **Cr**	25	26	27	28	29 **Cu**	30 **Zn**	31	32	33	34	35	36

(i) Which of the elements shown, shows behaviour closest to that of an ideal gas? (6)

(ii) Explain
  (*a*) why atomic radius decreases going from aluminium to chlorine,
  (*b*) why atomic radius increases going from nitrogen to phosphorus,
  (*c*) why the atomic radii of chromium, copper and zinc are very similar? (12)

(iii) One of the elements, whose symbol is given in the table above, melts at 172 K. At temperatures above 239 K it is a gas which is denser than air. Identify the element and state a common use for it. Write an equation for the reaction of water with the compound formed between this element and aluminum. (12)

(iv) Define *electronegativity*. Both nitrogen and phosphorus combine with hydrogen to form gaseous hydrides. Which of these hydrides would you expect to be readily soluble in water?
Give reasons for your choice. (15)

(v) Write the electronic configurations (s, p, etc.) for chromium <u>and</u> copper and explain why these two elements are exceptions to the normal order in which electrons occupy sublevels. (15)

(vi) Chromium, copper and zinc are all classified as d-block elements but only chromium and copper are classified as transition elements. Explain why this is the case. (6)

5. Define (a) heat of formation, (b) heat of combustion, (c) heat of neutralisation. (18)

The heats of formation of carbon dioxide and water were found by experiment to be –394 kJ mol^{-1} and –286 kJ mol^{-1} respectively. The heat of formation of ethanoic acid could not be found directly by experiment but its heat of combustion was found to be –876 kJ mol^{-1}.

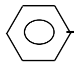
(i) Explain why it is possible to measure experimentally the heats of formation of carbon dioxide and water but not that of ethanoic acid. (6)

(ii) Use the heats of formation of carbon dioxide and water, together with the heat of combustion of ethanoic acid, to calculate the heat of formation of ethanoic acid. (12)

(iii) Outline how you would measure the heat of neutralisation of ethanoic acid by sodium hydroxide in the school laboratory. (15)

(iv) In an experiment to find the value of the heat of neutralisation of ethanoic acid it was found that when 50 cm^3 of a 1.0 mol dm^{-3} solution of ethanoic acid were neutralised, 2.79 kJ of heat energy were produced. When a similar heat of neutralisation experiment was carried out using 50 cm^3 of a 1.0 mol dm^{-3} solution sulphuric acid, 5.72 kJ of heat energy were released. Calculate the heat of neutralisation of each acid and suggest a reason, other than experimental error, for the difference in the two values for the heats of neutralisation obtained. (15)

6. The structural formulae of five organic compounds are given as follows:

A	**B**	**C**	**D**	**E**
$\mathbf{CH_3CH_2CH_2CH_3}$	$\mathbf{CH_3COCH_3}$	$\mathbf{CH_2{=}CHC{\equiv}N}$	$\mathbf{CH_3COOCH_3}$	 $\mathbf{—CH{=}CH_2}$

(i) Give the systematic (IUPAC) names of **A, B, C, D** and **E**. (15)

(ii) Which of the five compounds is an alkane? Give the name <u>or</u> formula of another alkane which is a liquid at room temperature and pressure. (6)

(iii) Which of the five compounds is aromatic? By what name is this compound more commonly known? Write down (a) the molecular formula, (b) the empirical formula of this compound. (12)

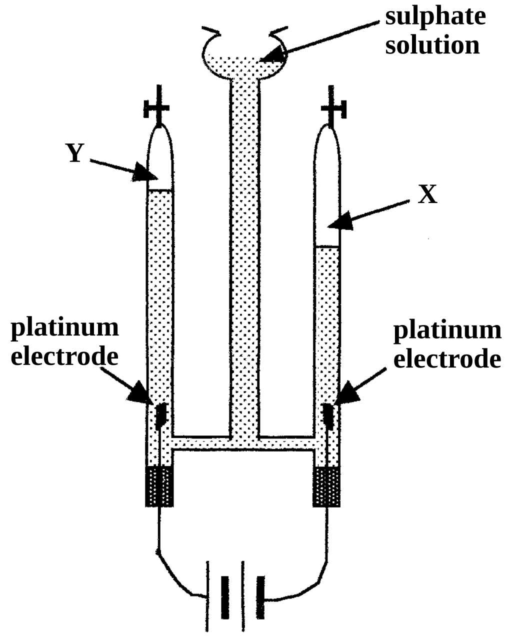
(iv) Which of the five compounds is a structural isomer of a carboxylic acid? Give the name and structural formula of the acid. (9)

(v) Which of the five compounds can be reduced to a secondary alcohol?
How can this reduction be carried out? (12)

(vi) Which <u>two</u> of the compounds can be used to make addition polymers? Draw the structure of one of these polymers showing two repeating units. (12)

7. (*a*) State *Faraday's first law of electrolysis*. (6)

The diagram shows an apparatus in which the electrolysis of aqueous sodium sulphate using inert (platinum) electrodes is being carried out.



(i) Identify the gases, **X** and **Y**. (6)

(ii) Write equations for the reactions taking place at the anode and cathode. (12)

(iii) If 45 cm^3 of gas **Y**, measured at room temperature and pressure, were produced in 386 seconds, what constant current was used and what volume of gas **X** was produced? (Molar volume at room temperature and pressure = 24.0 dm^3). (12)

(*b*) Sodium is obtained commercially from sodium chloride by electrolysis in the Downs cell which has a central anode made of material **A** and a circular cathode made of material **B**. The melting point of sodium chloride is 800 ^oC but the molten electrolyte used in the cell melts at about 600 ^oC.

(i) Why is it necessary to use an electrolytic method for the extraction of sodium? (6)

(ii) Explain why the electrolyte in the Downs cell melts at a temperature well below the melting point of sodium chloride. What is the advantage of the lower melting point of the electrolyte? (6)

(iii) What is the other product of the electrolysis? Write an equation for the reaction in its production. (9)

(iv) Identify the two materials, **A** and **B**. Why is material **B** not used for the anode? (9)

8. Explain the terms (a) flocculation, (b) pH, (c) acid dissociation constant (K_a), (d) conjugate pair. (18)

Give the name <u>or</u> formula of a flocculating agent commonly used in water treatment.
What is added in the water treatment process (a) if the pH is found to be too low, (b) if the pH is found to be too high? (9)

The value of the acid dissociation constant (K_a) for chloric(I) acid at 25 ^oC is 3.7 x 10^{-8} mol dm^{-3}. The equation for the dissociation of the acid in aqueous solution is

$$\mathbf{HClO} \quad + \quad \mathbf{H_2O} \quad \rightleftharpoons \quad \mathbf{H_3O^+} \quad + \quad \mathbf{ClO^-}$$

(i) Write down the conjugate pairs in the dissociation of chloric(I) acid in aqueous solution. (6)

(ii) Give the expression for the acid dissociation constant (K_a) of chloric(I) acid. (6)

(iii) Is chloric(I) acid strong or weak? Give a reason for your answer. (6)

(iv) Calculate the approximate pH of a 0.5 mol dm^{-3} solution of chloric(I) acid at 25 ^oC. Give your answer correct to two significant figures. (9)

(v) Calculate the approximate percentage dissociation of chloric(I) acid in a 0.1 mol dm^{-3} solution at 25 ^oC. Give your answer correct to one significant figure. (12)

9. State (a) *Le Chatelier's principle*, (b) *Dalton's law of partial pressures*. (12)

A mass of 16.68 g of phosphorus(V) chloride was heated in a sealed 5 dm^3 vessel at 600 K. When equilibrium had been reached at that temperature, the mass of phosphorus(III) chloride present was found to be 8.25 g. The equation for the reaction is

$$\mathbf{PCl_{5(g)}} \quad \rightleftharpoons \quad \mathbf{PCl_{3(g)}} \quad + \quad \mathbf{Cl_{2(g)}} \qquad \mathbf{\Delta H \ = \ 124\ kJ}$$

(i) Write the equilibrium constant (K_c) expression for the reaction and calculate the value of K_c at 600 K. (21)

(ii) Use the equation of state for an ideal gas to calculate the total pressure in the reaction vessel at equilibrium. Express the pressure in atmospheres (1 atmosphere = 1 x 10^5 Pa) giving your answer correct to one decimal place. (9)

(iii) Write the equilibrium constant (K_p) expression for the reaction and calculate the value of K_p for the reaction in atmospheres at 600 K. (18)

(iv) Would the values of the equilibrium constants (K_c and K_p) have been greater, less or unchanged if the reaction were carried out at 700 K? Explain your answer. (6)

10. Answer any *two* of the following.

(*a*) Sulphur, a solid at room temperature, is an element which exists in a number of *allotropic forms*. It is used in the manufacture of sulphuric acid by the Contact process. Some of the acid produced is combined with ammonia to produce ammonium sulphate, a widely used fertiliser.

(i) What is meant by *allotropic forms*? (6)

(ii) Starting with sulphur, outline the steps involved in the manufacture of sulphuric acid by the Contact process. (12)

(iii) Write an equation for the reaction in which ammonium sulphate is formed from ammonia and sulphuric acid. (6)

(iv) A compound (NPK) fertiliser was produced containing 5 per cent of nitrogen by mass. If ammonium sulphate was the only nitrogen compound used, what mass of it, to the nearest kilogram, was required to make one tonne of the fertiliser? (9)

(*b*) The complete combustion of 1.5×10^{-3} moles of a gaseous hydrocarbon required 84 cm^3 of oxygen (measured at S.T.P.) and produced 27 mg of water.

(i) How many moles of oxygen would be used up and how many moles of water would be produced if one mole of the hydrocarbon were burned in oxygen. (12)

(ii) Show clearly that the gaseous hydrocarbon is ethyne (C_2H_2). (9)

(iii) What is the product of the hydration of ethyne? What reagents and conditions are required for this hydration? (12)

(*c*) Classify each of the oxides in the following list as acidic, basic, amphoteric or neutral.

$$\mathbf{Al_2O_3} \qquad \mathbf{CO} \qquad \mathbf{MgO} \qquad \mathbf{CO_2}$$ (12)

(i) Write an equation for the reaction of the acidic oxide with sodium hydroxide. (6)

(ii) Write an equation for the reaction of the basic oxide with water. (3)

(iii) Write an equation for the reaction of the amphoteric oxide with (a) hydrochloric acid, (b) sodium hydroxide. (12)

(*d*) Define *oxidation number.* (6)

In a laboratory experiment, carried out at room temperature and pressure, a student added 1 cm^3 of a solution of potassium manganate(VII) to 25 cm^3 of an acidified solution of ethanedioic acid and noted the time taken for the purple colour to disappear. The student then added another 1 cm^3 of the potassium manganate(VII) solution and found that the time required for the colour to disappear was shorter. The unbalanced equation for the reaction is

$$\mathbf{H^+ + MnO_4^- + C_2O_4^{2-} \rightarrow CO_2 + Mn^{2+} + H_2O}$$

(i) Show using oxidation numbers that the reaction is an oxidation-reduction reaction and show clearly where oxidation and reduction have taken place. Using this information, balance the equation. (18)

(ii) Explain clearly why the decolorising time became shorter when the second portion of the potassium manganate(VII) solution was added. (9)

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