AN ROINN OIDEACHAIS

LEAVING CERTIFICATE EXAMINATION, 1980

CHEMISTRY—HIGHER LEVEL

FRIDAY, 20 JUNE—AFTERNOON, 2 to 5

Six questions to be answered

All questions carry the same number of marks.

Relative atomic masses: H = 1, C = 12, N = 14, O = 16, S = 32, Cr = 52, Fe = 56, I = 127

Molar volume at S.T.P. = 22·4 litres (dm^3)

Avogadro constant (number) = 6×10^{23}

R(general gas constant) = 8·4 Nm mol^{-1} K^{-1} = 0·082 l atm mol^{-1} K^{-1}

1 atmosphere = $1{\cdot}013\times10^5$ Nm^{-2} = 760 mm Hg

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

   (a) Write the equation for any one reaction in which a precipitate is formed and name the precipitate.

   (b) Sodium carbonate crystals ($Na_2CO_3.10H_2O$) are efflorescent. Explain the meaning of the word underlined.

   (c) How many molecules of oxygen are there in 4 g of oxygen gas at S.T.P.?

   (d) If an electron with energy E_1 moves to a lower level where its energy is E_2, the quantum of energy emitted is given by the expression $E_1-E_2 = h\nu$. What is h called? What does ν represent?

   (e) Write the formula of (i) isobutane (2-methylpropane), (ii) sec-butyl alcohol (butan-2-ol).

   (f) Name the instrument used in each case (i) to identify isotopes of elements,
   (ii) to measure the angle of rotation of an optically active compound in solution.

   (g) Explain what is meant by saying that carbon-14 has a half-life of 5570 years.

   (h) Name a polymer with the linkages $-\overset{\overset{O}{\|}}{C}-\overset{\overset{H}{|}}{N}-$

   (i) Give an example of one molecule in each case, the shape of which is associated with
   (i) sp, (ii) sp^3, hybridisation of orbitals.

   (j) Describe how you would confirm the presence of nitrate ions in aqueous solution.

   (k) How many faradays of electricity are needed for the discharge of 13g of Cr^{3+} ion at an inert electrode?

   (l) What volume of 1M sulphuric acid solution must be added to 100 cm^3 of 1M sodium hydroxide solution in order to neutralise it?

   (m) Define the hydration energy of an ion.

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

2. Answer this question by taking examples, where necessary, from the first thirty-six elements of the Periodic Table. (Mathematics Tables p. 44)

   (i) State, giving reasons, how you would expect atomic radius to change across a period.

   (ii) Write the s, p etc. configurations of the elements with atomic numbers of 15 and 21.

   (iii) Name one element which, in the solid state, conducts electricity and explain clearly why it is able to do so.

   (iv) Name one common transition element and mention two specific properties of the element or its compounds which are characteristic of transition elements.

   (v) How many unpaired electrons are there in an atom of the element you selected in (iv)?

   (vi) Name one ionic hydride, state its appearance at room temperature and show by an equation how it reacts with water.

   (vii) Name one covalent hydride, state its appearance at room temperature and show by an equation how it reacts with water. If the hydride you select does not react with water suggest a reason for this.

   (viii) Give the formula of one chloride formed by a non-metal and which is hydrolysed by water. State its appearance at room temperature and give an equation for its hydrolysis.

3. State (a) Dalton's Law of Partial Pressures, (b) Graham's Law of Diffusion.

The general gas equation for an ideal gas is given as $PV = nRT$.

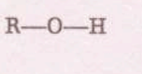
(i) What is an ideal gas? What does the quantity n represent in this equation?

(ii) Give two reasons why real gases differ from ideal behaviour. State, giving your reason, which of the gases hydrogen, oxygen, hydrogen chloride or methane you would expect to differ most from ideal behaviour at room temperature.

(iii) 1·1 g of a gas occupied $3{\cdot}15 \times 10^{-4}\ m^3$ at 300K and at a pressure of $10^5\ Nm^{-2}$. Use the general gas equation to calculate the relative molecular mass (molecular weight) of the gas.

4. **A, B, C, D,** and **E** represent five different types of organic compounds with different functional groups. The R represents an alkyl group in each compound.

A



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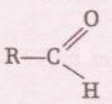

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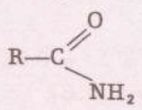

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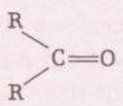

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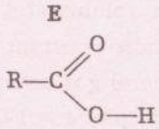


(i) What is a functional group?

(ii) In each case name the series of compounds to which the group shown belongs.

(iii) Select one compound representative of the series to which each of **A, B, C** and **D** belong and for each compound chosen indicate by an equation one chemical reaction which you consider typical of the functional group present.

(iv) Describe, with the aid of a labelled diagram, how you would convert a compound containing functional group **A** into one containing functional group **E.**

5. Describe, with the aid of a suitable diagram, how the depression of freezing-point of a pure solvent by a non-volatile solute may be measured experimentally. Mention any necessary precautions that should be taken to ensure the accuracy of the result.

2 g of urea (NH_2CONH_2) depressed the freezing point of 200 g water by 0·31 K. Calculate the freezing point constant for 1 kg water.

The freezing point of a solution of m-dinitrobenzene (1,3-dinitrobenzene i.e. $C_6H_4(NO_2)_2$) in acetic acid (ethanoic acid) is 1·3 K lower than that of the pure acid. If the freezing point constant for acetic acid (ethanoic acid) is 3·9 K $mol^{-1}kg^{-1}$,

(i) calculate the mass of m-dinitrobenzene (1,3-dinitrobenzene) per kg of acetic acid (ethanoic acid),

(ii) calculate the mole fraction of m-dinitrobenzene (1,3-dinitrobenzene) in the solution.

6. Define oxidation in terms of (i) electron transfer, (ii) change in oxidation number.

In the following examples indicate clearly, by showing electron loss or gain, which species is being oxidised and which is being reduced:

(i) $2KI + Cl_2 \longrightarrow 2KCl + I_2$

(ii) $Fe + 2HCl \longrightarrow FeCl_2 + H_2$

State the oxidation number or numbers that apply to:

(i) an atom of a free element,

(ii) a simple ion,

(iii) oxygen in its compounds,

(iv) hydrogen in its compounds,

(v) a neutral molecule.

In the case of any *two* of the following reactions, indicate clearly, by showing the changes in the oxidation numbers, which species is being oxidised and which is being reduced.

(i) $2HgCl_2 + SnCl_2 \longrightarrow Hg_2Cl_2 + SnCl_4$

(ii) $NH_4NO_3 \longrightarrow N_2O + 2H_2O$

(iii) $3Cl_2 + 6OH^- \longrightarrow 5Cl^- + ClO_3^- + 3H_2O$

Using oxidation numbers or otherwise balance the following equation,

$$Zn + NO_3^- + H^+ \longrightarrow Zn^{2+} + N_2H_4 + H_2O.$$

7. **A** is a colourless liquid insoluble in water. Analysis shows it contains 91·3% carbon and 8·7% hydrogen by weight.

When **A** is refluxed with potassium permanganate and sodium hydroxide solution it is oxidised to a colourless solution containing a salt **B**. When this solution is acidified with dilute hydrochloric acid a white precipitate, **C** is formed. **C** is separated by filtration.

If some of the solid **C** is heated with soda-lime a colourless liquid, **D**, is formed. When **D** is heated with a mixture of concentrated nitric and sulphuric acids it gives a substitution product, **E**.

Reduction of **E** by tin and concentrated hydrochloric acid gives a liquid, **F**, usually yellow or brown in colour. Compound **F** is insoluble in water but dissolves in dilute sulphuric acid. Acetic anhydride (ethanoic anhydride) converts **F** to a white crystalline derivative, **G**.

(i) Write the name of any *six* of the compounds **A, B, C, D, E, F, G.**

(ii) Give the structural formula of each of the six compounds chosen.

(iii) Write equations for the reactions **B** to **C, D** to **E** and **F** to **G.**

(iv) All the listed compounds, **A** to **G,** have one common structural feature. Identify this common feature and briefly explain the bonding present.

8. *(a)* Define (i) an acid, (ii) a base, in terms of the Brønsted-Lowry theory.
State one merit of this theory compared to the Arrhenius theory.

Indicate the species which is acting as an acid on the left hand (reactant) side of each equation and in each case indicate its conjugate base.

(i) $HS^- + H_2O \rightleftharpoons OH^- + H_2S$

(ii) $H_2SO_4 + HF \rightleftharpoons H_2F^+ + HSO_4^-$

(iii) $H_3PO_4 + NH_3 \rightleftharpoons H_2PO_4^- + NH_4^+$

(b) Define the pH of a solution.
Find the pH of an aqueous solution containing 1·48 g of propionic (propanoic) acid (CH_3CH_2COOH) in 200 cm^3 solution, given that the dissociation constant (K_a) for propionic (propanoic) acid is $1{\cdot}36 \times 10^{-5}$.

Explain the following observations.

(i) Propionic (propanoic) acid is soluble in water while pentane, which has almost the same relative molecular mass (molecular weight), is insoluble.

(ii) When 25 cm^3 of a 0·1 M solution of sodium hydroxide is added to 25 cm^3 of a 0·1 M solution of hydrochloric acid the resultant solution has a pH of 7, but when 25 cm^3 of a 0·1 M solution of sodium hydroxide is added to 25 cm^3 of a 0·1 M solution of propionic (propanoic) acid, the pH of the solution is about 9.

9. The equilibrium between hydrogen, iodine and hydrogen iodide in the gaseous state was investigated as follows:

560 cm^3 hydrogen (measured at S.T.P.) was placed in a 1000 cm^3 flask together with 6·35 g solid iodine. The flask was sealed and heated for 30 mins. at 700 K. It was then cooled rapidly and, on analysis, the mass of hydrogen iodide present was found to be 5·12 g.

(i) Write the equilibrium constant expression for the reaction, $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

(ii) What change does the iodine undergo as the vessel is heated?

(iii) What was the purpose of the rapid cooling?

(iv) Calculate the equilibrium constant (K) for this reaction at 700K.

(v) If the experiment were repeated using the same quantities of hydrogen and iodine in a 500 cm^3 flask, state, giving your reason, whether or not, the value of K obtained would have been different.

(vi) For the reaction in (i) K has a lower value at 800K than at 700K. State and explain what conclusion can be drawn regarding the heat change for the reaction.

10. Answer any *two* of the following.

(a) Outline the main energy changes involved when butane gas burns in air.
What information, apart from the names of the reactants and products, is conveyed by the equation?

$$2C_4H_{10(g)} + 13O_{2(g)} \longrightarrow 8CO_{2(g)} + 10H_2O_{(l)} \quad \Delta H = -5754\ kJ$$

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 heat of formation of butane.

(b) Explain briefly, giving reasons in qualitative terms, how the rate of an all-gaseous chemical reaction is usually affected by

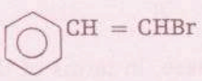
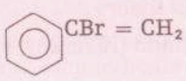
(i) increasing the concentration of one reactant,

(ii) increasing the pressure,

(iii) increasing the temperature,

(iv) introducing a suitable catalyst.

(c) Explain, as fully as you can, each of the following observations.

(i) There are two isomers of formula  but there is only one compound of formula 

(ii) Carbon dioxide is a gas at room temperature but silicon, which is in the same group as carbon, forms a solid dioxide with a very high melting-point.

(d) $25\ cm^3$ of a solution containing iron (II) sulphate required $18{\cdot}5\ cm^3$ of 0·02 M potassium permanganate solution for oxidation in acidic conditions. Calculate the number of grams of anhydrous iron (II) sulphate per litre (dm^3) of the solution. Why are acidic conditions essential for the titration and how is the end-point determined?