SECTION I: Multiple Choice Questions

Select the SINGLE best alternative in each of the following cases and indicate your answer by marking the corresponding letter on the answer sheet provided, according to the instructions on it.

QUESTIONS 1 TO 11

DIRECTIONS. These questions are arranged in groups.

Questions 1-5 concern various compounds whose bonding is described below.

A Dative covalent and covalent.
B Dative covalent, covalent and ionic.
C Covalent bonding and dipole/dipole forces.
D Covalent and intermolecular hydrogen bonding.
E Covalent without intermolecular hydrogen bonding nor dipole/dipole forces.

Select, from A to E, the best description of the types of bonding present in each of the following substances. Each description may be used once, more than once, or not at all.

1) Liquid hydrogen fluoride.
2) The ammonia/boron trifluoride addition compound NH_3BF_3.
3) Solid ammonium chloride.
4) Liquid hydrogen chloride.
5) Liquid bromine.

Questions 6-11

The following questions concern the shapes of molecules or ions which may be described as

A planar
B trigonal pyramidal
C tetrahedral
D trigonal bipyramidal
E v-shaped

Select from A to E the expected shape of the following. Each description may be used once, more than once, or not at all.

6) ammonium ion, NH_4^+
7) methane, CH_4
8) Water, H_2O
9) boron trifluoride, BF_3
10) nitrogen trichloride, NCl_3
11) phosphorus pentafluoride, PF_5

Questions 12-17

The following questions concern the following classification of the elements.

A noble gases
B s-block
C p-block
D d-block
E f-block

Select from A to E the location of

12) the element aluminium
13) the element with the electronic configuration 2.8.1
14) the element with the electronic configuration $1s^22s^22p^63s^23p^63d^14s^2$.
15) the element with the configuration $[Ar]3d^{10}4s^24p^3$
16) the element whose **ANION** has the electronic configuration $1s^22s^22p^63s^23p^6$
17) the element with atomic number 10.

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18) Which one of the following species has an electronic configuration which may be represented by $[Ar]3d^34s^0$. (Relevant atomic numbers are given at the beginning of this section.)
A Fe^{2+}.
B Iron as the free element.
C Mn^{2+}.
D Vanadium as the free element
E Cr^{3+}.

19) Which one of the following species has three unpaired electrons in the 2p sub-shell?
A a hydrogen atom.
B an oxygen atom.
C a boron atom.
D a nitrogen atom.
E a phosphorus atom.

20) Nitrogen (RAM = 14.0) and fluorine (RAM = 19.0) form a compound, 8.25 g of which contain 3.50 g of nitrogen. What is the empirical formula of the compound?
A NF
B NF_2
C N_2F
D NF_3
E N_2F_3

21) Ethanol has a lower boiling point than water partly because
A it is a covalent compound.
B its molecules have less tendency to form hydrogen bonds.
C it has a larger molecular mass.
D it does not contain ionic bonds.
E it contains carbon atoms.

22) X moles of sodium chlorate(V) decomposed on heating to release 120 cm^3 of oxygen.

$$2NaClO_3(s) \rightarrow 2NaCl(s) + 3O_2$$

How many moles of sodium chlorate decomposed? (The molar volume of a gas under the same conditions is 24 dm^3mol^{-1}.)
A 0.167×10^{-3}
B 0.250×10^{-3}
C 1.67×10^{-3}
D 2.50×10^{-3}
E 3.33×10^{-3}

23) Which one of the following molecules has a dipole moment?
A I_2
B O_2
C N_2
D F_2
E HF

24) A colourless solution gives a brown precipitate when treated with sodium hydroxide solution. The precipitate is insoluble in excess. Which one of the following ions is most likely to be present?
A silver
B iron(II)
C dichromate
D copper(II)
E sulfite

25) A solution gives a white precipitate with barium chloride solution. The precipitate is insoluble in dilute nitric acid. The original solution contained:
A sulfate
B nitrate
C sulfate
D carbonate
E chromate

SECTION II: Structured Questions

Answer each of the following questions in the spaces provided on the question paper. Full marks can only be awarded for numerical questions where working is shown. Underline your answers.

1) The standard enthalpies of formation of methanol, methanal and water are -240, -118, and -286 $kJmol^{-1}$, respectively.

a) i) Define *standard enthalpy of formation.* (2 marks)

ii) Calculate the standard enthalpy change for the oxidation by oxygen of methanol ($CH_3OH(l)$) to methanal ($CH_2O(g)$) and water. (The substances are in their standard states.) (3 marks)

c) i) Distinguish between ***mean bond enthalpy*** and ***bond dissociation enthalpy***. (4 marks)

ii) The standard enthalpy of atomization of methanal is +1567 $kJmol^{-1}$, and the C-H bond enthalpy term is +412 $kJmol^{-1}$. Calculate the C=O bond enthalpy term. Note: the structure of methanal is (3 marks)

2) An organic ester, X, contains 54.55% C, 9.09% H, and 36.36% O by mass.

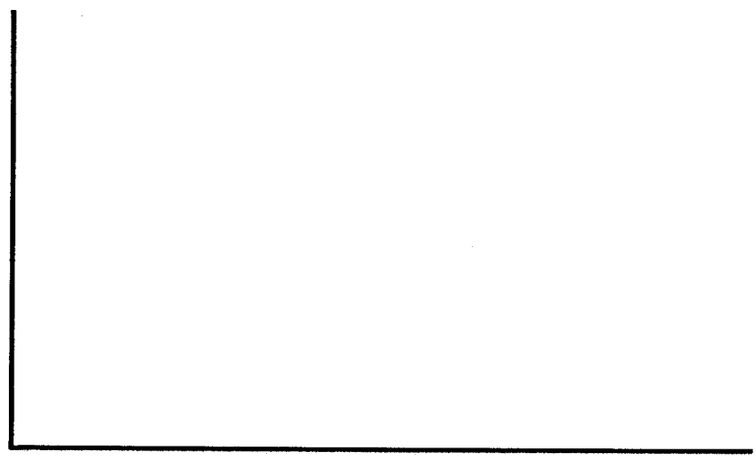
a) Determine the empirical formula of X. (RAM of H = 1.00, C = 12.0, O = 16.0) (3 marks)

b) 0.15 g of X, when vaporized in a suitable apparatus, occupied a volume of 57.0 cm^3 at 127 °C and 1.00×10^5 Nm^{-2}. Calculate the relative molecular mass of X. (R = 8.31 J K^{-1} mol^{-1} or 0.0821 L atm mol^{-1} K^{-1}.) (3 marks)

What is the molecular formula of X? (1 mark)

3) a) In what principal ways does a real gas differ from an ideal gas? (2 marks)

b) In a real gas the particles do not all travel at the same speed. Demonstrate this statement by sketching on the axes below the distribution of speeds at two temperatures T_1 and T_2, T_2 being much greater than T_1. Label the axes. (4 marks)



c) A mixture of gases, containing nitrogen and oxygen in the mole ratio 3:2 respectively, has a volume of 76.0 cm^3 at 91 °C and 800 mmHg pressure.

i) Calculate the volume of the mixture at s.t.p. (3 marks)

ii) Determine the partial pressures of nitrogen and oxygen in the mixture at s.t.p. (2 marks)

4) The following question concerns the electronic structures of various atoms, ions and molecules.

a) Give the ground state electronic configurations of the following (in the form $1s^2 2s^2 2p_x^1$ etc.). (3 marks)

Ca^{2+} _____

O^{2-} _____

Ar _____

Cu _____

Cu^{+} _____

Cu^{2+} _____

b) Write the formulae of two of the above which are isoelectronic with each other. (1 marks)

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c) Draw Lewis electron-dot diagrams to show the bonding in the following. Include all valence electrons. (5 marks)

i) nitrogen molecule

ii) carbon dioxide molecule

iii) nitrate ion

iv) sulfur hexafluoride molecule, SF_6

v) the tri-iodide ion, I_3^-. (Iodine is in group 7.)

d) Use VSEPR theory to predict the shapes of the sulfur Hexafluoride (SF_6) molecule and the tri-iodide ion. Explain your reasoning carefully. (If you do not know the descriptive term, draw a diagram.) (6 marks)

5) Potassium chloride is a white crystalline solid at room temperature and pressure. It has a **high melting point**, is **soluble in water** and **conducts electricity** in aqueous solution.

a) Use your knowledge of ionic bonding to explain in detail any TWO of the above mentioned properties (indicated in bold) of the compound. (4 marks)

b) CH_4, C_2H_6, and C_3H_8 are non-polar covalent compounds. Predict, with reasoning, which of the three compounds you would expect to have the highest boiling point. (3 marks)

c) Water has a much higher boiling point than hydrogen sulfide. Explain this observation. (3 marks)

SECTION III: Essay questions

There are three questions in this section. Select any ONE and answer it on the lined paper provided. Use the following relative atomic masses as necessary.

C = 12.01, O = 16.00, H = 1.008

1) 1.576 g of pure oxalic acid, $(CO_2H)_2.2H_2O$, was weighed out accurately and transferred to a 250 cm^3 volumetric flask without loss. The acid was dissolved and made up to the mark with water. 25 cm^3 portions were accurately pipetted into a conical flask and titrated with the potassium permanganate solution. The mean of three concordant titres was 26.00 cm^3. Calculate the molarity of the potassium permanganate solution.

$$5(CO_2H)_2 + 2MnO_4^- + 6H^+ \rightarrow 8H_2O + 2Mn^{2+} + 10CO_2$$ (8 marks)

2) The atomic radius of atoms decreases across period 2 and increases down a group. Give a detailed explanation of these trends mentioning nuclear charge, the screening effect, and the effective nuclear charge." (8 marks)

3) 25 cm^3 of a gaseous hydrocarbon were mixed with excess oxygen until the total volume was 191 cm^3. The mixture was then ignited and after cooling the volume of gas was measured as 116 cm^3. The gases were then shaken with concentrated potassium hydroxide to give a final volume of 16 cm^3. The oxygen was more than enough to consume all the hydrocarbon, and the gas volumes were all measured at the same temperature and pressure.
Write a general equation for the reaction of a hydrocarbon C_xH_y with oxygen, and an equation for the reaction of carbon dioxide with potassium hydroxide in solution. Determine the volume of oxygen which actually reacted with the hydrocarbon and the volume of carbon dioxide formed. Use the volumes determined above, or otherwise, to find the formula of the hydrocarbon. (8 marks)