General Certificate of Education (Adv. Level) Examination, 2025

Chemistry -II

Three Hours

- ***This question paper consists of 15 pages.***
- ***Answer all the questions.***
- ***The use of calculators is not permitted.***
- ***Write your name in the space provided on the answer script.***

Name:

Universal gas constant: $R = 8.314\ J \cdot K^{-1} \cdot mol^{-1}$ **Planck's constant = 6.626×10^{-34} J s**

Avagadro Constant, $N_a = 6.022 \times 10^{23}\ mol^{-1}$ **Speed of light: $c = 3 \times 10^{8}\ ms^{-1}$**

Section A – Structured Essay

1. a) The following questions are related to the elements of the second row in the Periodic Table.

   Write the **symbol** of the element in the space provided in answering parts (i) to (vi).

   i) Identify the element that has the highest electronegativity. (disregard the noble gas). ……...

   ii) Identify the element that has an allotrope which conducts electricity. …….

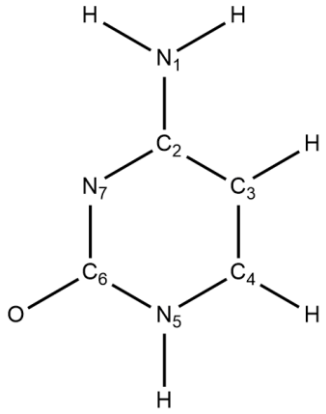
   iii) Identify the element that forms the monoatomic ion largest in size (This should be a stable ion). …….

   iv) Identify the element that has **no** *p* electrons but has a stable *s* configuration. …….

   v) Identify the element that has the highest first ionization energy. …….

   vi) Identify the element that forms mostly electron deficient trigonal planar covalent compounds. …….

b) Cytosine is a nitrogenous base belonging to the pyrimidine family. Its skeleton is given below. Molecular formula $C_4H_5N_3O$.



i) Draw the most acceptable Lewis structure for this compound.

ii) Draw three resonance structures for the above structure.

iii) Write down the electron pair geometry, the shape around the atoms, the hybridization, and the approximate value of the bond angle around the atoms of **C_2, N_1, N_7** atoms in the table given below.

	N_1	**N_7**	**C_2**
1)The electron pair geometry			
2)The shape around the atoms			
3)The hybridization of the atom			
4)The approximate value of the bond angle			

iv) State whether **N_1** or **N_7** has more electronegativity in the Lewis structure drawn in part i) above.

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Give reasons for your answer.

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v) In the above (i) section, indicate the atomic/hybrid orbitals involved in forming the sigma bonds in the lewis structure.

i) N_1-H N_1…… H……

ii) N_7-C_2 N_7…… C_2……

iii) C_6-O C_6…… O……

c) Arrange the following in increasing order based on the given property in brackets. (explanations are not required).

i) B, Na, P, Be, N (First Ionization Energy)

……<……..<……<……<……

ii) NH_4^+, NF_3, NH_3, NOCl, NO_2^+ (Bond Angle)

……<……<……..<……<……

iii) NH_3, NOCl, NO_2Cl, NH_4^+, CF_3CN (Electronegativity of Nitrogen)

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2. a) **X** is an *s*-block element in the periodic table. The first, second and third ionization energies of **X**, in kJ mol^{-1} are 738, 1451 and 7733 respectively. **X** reacts slowly with hot water, liberating H_2 (g) and forming its hydroxide. The hydroxide is basic. **X** also liberates H_2 (g) on reaction with dilute acids. **X** burns in air with a bright white light. The cation of **X** contributes to hardness of water.

i) Identify **X.** **X:** …….

ii) Write the ground state electronic configuration of **X**. ……

iii) Write the chemical formulae of the two compounds formed when **X** burns in air.

…….and ……

iv) Consider the given compounds of the elements in the group in the Periodic Table to which **X** belongs. In the given boxes, write whether the indicated property **increases** or **decreases** down the group.

I. Solubility of sulphates in water

II. Solubility of hydroxides in water

III. Thermal stability of metal carbonates.

Give reasons for your answer in III.

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v) Identify the element in the *s*-block of the periodic table, which reacts in a similar manner to **X** with H_2(g), O_2(g) and N_2(g), but does **not** belong to the same group as **X**.

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vi) Identify another **metal ion** that contributes to hardness of water from the group of **X**.

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vii) **X** is a component of a well-known reagent used in organic chemistry. Give the **name** of this reagent.

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b) Six unidentified aqueous solutions labeled as **P, Q, R, S, T**, and **V** were tested. These solutions contain NaOH, Na_2CO_3, $BaCl_2$, NH_4Cl, $MgCl_2$, and H_2SO_4 (not in this order).

Two solutions were mixed at a time, and the observations were recorded as follows:

	Observation
P + V	A white precipitate formed, which decomposes upon heating to release an acidic gas.
P + S	A colorless gas is evolved that turns lime water milky.
S + Q	A white precipitate formed, insoluble in acids.
R + T	A clear solution formed.NH_3 gas is evolved.
P + R	A clear solution formed. Upon heating the solution released both acidic and basic gases. The basic gas produced a brown coloration when exposed to filter paper moistened with Nessler's reagent.

i) Identify the aqueous solutions **P** to **V** based on the observations.

P…… Q…….

R…… S……..

T……. V…….

ii) Write balanced chemical equations for all the cases mentioned above. Denote the precipitate as ' ↓'.

I. P + V

Formation of the white precipitate.

…….

Decomposition of the precipitate upon heating.

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II. P + S

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III. S + Q

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IV. R + T

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V. P + R

Formation of the clear solution.

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Formation of acidic and basic gases upon heating.

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03. a) The following question is related to the experiment to find the molar volume of O_2 using $KMnO_4$.

Initial mass of the reaction vessel = 48.80 g

Final mass of the reaction vessel = 48.20 g

Collected O_2 gas volume = 380 cm^3

Room temperature = 27 °C

Atmospheric pressure = 760 mm Hg

Saturated vapor pressure of water at 27 °C = 26 mm Hg

i) Write the balanced chemical equation for the above decomposition of $KMnO_4$.

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ii) Calculate the number of moles of O_2 produced here.

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iii) Find the volume occupied by the above calculated moles of O_2 under standard conditions.

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iv) Find the molar volume of O_2.

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v) Mention two possible errors in this test.

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b) Write balanced chemical equations for the processes related to the following statements:

i) The standard electron gain enthalpy (ΔH^{θ}_{EG}) of bromine is -328.0 kJ mol^{-1}.

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ii) The standard enthalpy of formation (ΔH^{θ}_{f}) of $MgCl_2(s)$ is -641.0 kJ mol^{-1}.

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iii) The standard enthalpy of combustion (ΔH^{θ}_{c}) of $C_{17}H_{35}COOH$ (s)(stearic acid) is -11380.0 kJ mol^{-1}.

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iv) The standard atomization enthalpy (ΔH^{θ}_{at}) of Mg(g) is 148.0 kJ mol^{-1}.

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v) The standard first ionization enthalpy of $Mg^{+}(g)$ (ΔH^{θ}_{IE1})is 737.0 kJ mol^{-1}.

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c) Consider the following reaction at 25°C:

$$AB(s) \rightarrow C(s) + D(g)$$

Below are the **standard enthalpy of formation (ΔH^{θ}_{f})** and **standard entropy (S^{θ})** values for the substances at 25°C .

	ΔH^{θ}_{f} / kJ mol^{-1}	**S^{θ} / J K^{-1} mol^{-1}**
AB(s)	-1208	100
C(s)	-600	50
D(g)	-500	170

i) Prove that the reaction is non-spontaneous at 25°C.

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ii) The reaction becomes spontaneous at temperature greater than T°C and remain non-spontaneous at temperature below T°C. Calculate T.

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04. a) **A, B, C,** and **D** are compounds with the molecular formula C_5H_{10}. These compounds do not exhibit diastereomerism or enantiomerism. Each compound reacts separately with conc. H_2SO_4, and the products are hydrolyzed. After hydrolysis **B** and **D** yield the same product, **E**. The products obtained from **A** and **C** are heated with Al_2O_3: **A** forms **F**, which shows diastereomerism. **C** forms **G**.

i) Draw the structures of **A, B, C, D, E, F**, and **G**.

A

B

C

D

E

F

G

ii) What type of diastereoisomerism does the **F** compound exhibit? Draw that isomers and name them. Draw the structure of the product after **F** react with H_2/Ni.

b) Write the mechanism between reaction between $C_2H_5CH=CH_2$ and Br_2 in CCl_4 .

Section B – Essay

05. i) Deduce Avogadro's law using the ideal gas equation PV= nRT.

ii) A certain bulb contains gas XeF_n under a pressure of 24 kPa. Hydrogen gas is injected into it and the total pressure in the vessel increases up to 96 kPa. Then allow the XeF_n and H_2 to react with an electric spark. Xe and HF gases are then formed. This mixture is reacted with a concentrated KOH solution to remove HF gas. The final pressure of Xe and the remaining H_2 is 48 kPa. Assume that all gases behave perfectly.

a) Find the value of n.

b) Find the partial pressure of HF before removing HF from the system.

b) The air consist of 78% by volume is Nitrogen (N_2), 21% Oxygen (O_2), 0.05% Carbon dioxide (CO_2), and the remainder is Argon (Ar). Atmospheric pressure is 1×10^5 Nm^{-2}.
(N = 14, O=16, C=12, Ar =39)

i) Find the partial pressures of each component.

ii) Calculate the density of air.

c) Consider the following reactions. Thermodynamic data supplied are **not** for the standard state.

	ΔH/kJ mol^{-1}	ΔS / J K^{-1} mol^{-1}
$C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$	130	140
$CO_2(g) + H_2(g) \rightarrow CO(g) + H_2O(g)$	40	50

i) Calculate ΔH and ΔS for the reaction $2CO(s) \rightarrow C(s) + CO_2(g)$. State giving reasons whether the sign of ΔS agrees with the reaction taking place.

ii) By means of a suitable calculation, predict whether the reaction given in part i) above is spontaneous at 27 ºC.

06. a) Solution **Y** contains **three** cations.

(A) The following tests were carried out to identify these cations.

Test	Observation
1)Dilute HCl was added to a small portion of **Y**.	A white precipitate **(P_1)** was formed.
2)**P_1** was separated by filtration and H_2S was bubbled through the solution.	A black precipitate **(P_2)** was formed.
3)**P_2** was separated by filtration. The filtrate was boiled to remove the H_2S, cooled, and NH_4OH/NH_4Cl was added.	No precipitate.
4)H_2S was bubbled through the solution.	A black precipitate **(P_3)** was formed.

(B) The following tests were carried out for precipitates **P_1, P_2,** and **P_3**.

Precipitate	Test	Observation
P_1	I)Water was added to **P_1**, and the mixture was boiled. II)The mixture from **I** above was filtered while warm and the following tests were carried out on the filtrate **(F_1)** and residue **(R_1)**. **Filtrate (F_1)** dilute H_2SO_4, was added to warm **F_1**. **Residue (R_1)** **R_1**was washed thoroughly with warm water and dilute NH_4OH was added. Thereafter, a KI solution was added.	Part of **P_1**, dissolved. A white Precipitate was formed. **R_1** dissolved. A dark yellow precipitate was formed.
P_2	**P_2** was dissolved in warm dil. HNO_3 and a potassium chloride solution was added.	Cooling the solution gave needle like crystals..

Precipitate	Test	Observation
P_3	I) **P_3** was dissolved in warm conc. HNO_3 . II) The following were added to **solution 1** above. • conc. HCl • dil. NH_4OH	A pink coloured solution **(solution 1)** A blue coloured solution **(solution 2)** A yellow-brown coloured **(solution 3)**

i) Identify the three cations, (Reasons are **not** required.)

ii) Identify,

1. Precipitates **P_1, P_2** and **P_3**.
2. Species responsible for the colours of **solutions** of **1, 2**, and **3**(**Note**: Write chemical formulae **only**.)

b) An aqueous solution **Q** contains **three** anions. The following tests were carried out to identify these anions.

(Fresh portions of solution **Q** were used for each test **(1)** to **(5)**.

	Test	Observation
(1)	I. Dilute HCl was added.	A colourless gas was evolved. A clear solution was obtained.
	II. The gas evolved was tested with filter paper moistened with lead acetate.	No colour change
(2)	I. A $BaCl_2$ solution was added.	A white precipitate was obtained.
	II. The white precipitate was separated by filtration, and dil. HCl was added to it.	The white precipitate dissolved with the evolution of a gas.
	III. The gas evolved was tested with a filter paper moistened with acidified potassium dichromate.	The colour changed from orange to green.
(3)	Conc. HNO_3 and an excess of ammonium molybdate solution were added and the mixture was warmed.	A yellow precipitate did not form.
(4)	Devarda's alloy and NaOH solution were added and the mixture was heated.	A gas that turned Nessler's reagent brown was evolved.
(5)	A $FeCl_3$ solution was added.	A blood red coloured solution was obtained.

i) Identify the three anions in solution **Q**.

ii) Write the balanced chemical equation for the reaction taking place in test number **(2) I, II** and **III.**

c) A certain organic compound made up of Carbon (C), Hydrogen (H), and Oxygen (O) was analyzed. In a 1.8 g sample, the compound was found to contain 0.72 g of Carbon, 0.12 g of Hydrogen, and the remaining mass as Oxygen.

i) Determine the mass of O.

ii) Find the empirical formula of the compound.

iii) If the relative molecular mass of the compound is **90**, determine its molecular formula. (C=12, H=1, O=16).

07. a) Answer these questions using the list given below.

CO_2, CH_4, volatile hydrocarbons, NO, NO_2, N_2O, NO_3^-, SO_2, H_2S, CFC, $CaCO_3$, liquid petroleum and coal

i) Identify two gaseous species that are responsible for acid rain and briefly explain, with the aid of balanced chemical equations, how these species cause acid rain.

ii) Acid rain has harmful effects on the environment. Briefly discuss this statement.

iii) Identify three species that are emitted to the environment due to the burning of fossil fuel, along with one adverse environmental issue for each.

iv) "The existence of trace amounts of industrial synthetic species in the atmosphere can cause adverse environmental issues." Explain this statement using CFC as an example.

v) Identify five greenhouse gases and state a human activity by which each of these gases enters the atmosphere.

b) The formula of chromite, a mineral containing Fe^{2+} and Cr^{3+}, is $FeO.Cr_2O_3$. A mass of 2.0 g was weighed from a deposit containing chromite mineral, ground to powder and dissolved in minimal dilute HCl. Adding excess Na_2O_2 solution to completely oxidize the cations. This makes the medium basic and solution became yellow in colour. Then excess H_2O_2 was removed by heating. The solution was then acidified with dilute H_2SO_4 to make 100.00 cm^3 of solution. This solution was orange in colour. 25.00 cm^3 of this was taken and then excess aqueous KI solution was added. Result in solution was titrated with 0.25 mol dm^{-3} $Na_2S_2O_3$. When the solution became pale, starch was added and then continued the titration with the $Na_2S_2O_3$.The burette reading of end point was 35.00 cm^3.

i) Write balanced chemical equations for the reactions of H_2O_2 with Cr^{3+} and Fe^{2+}in alkaline medium.

ii) Write the reactions that occur when KI is added to solution in acidic medium.

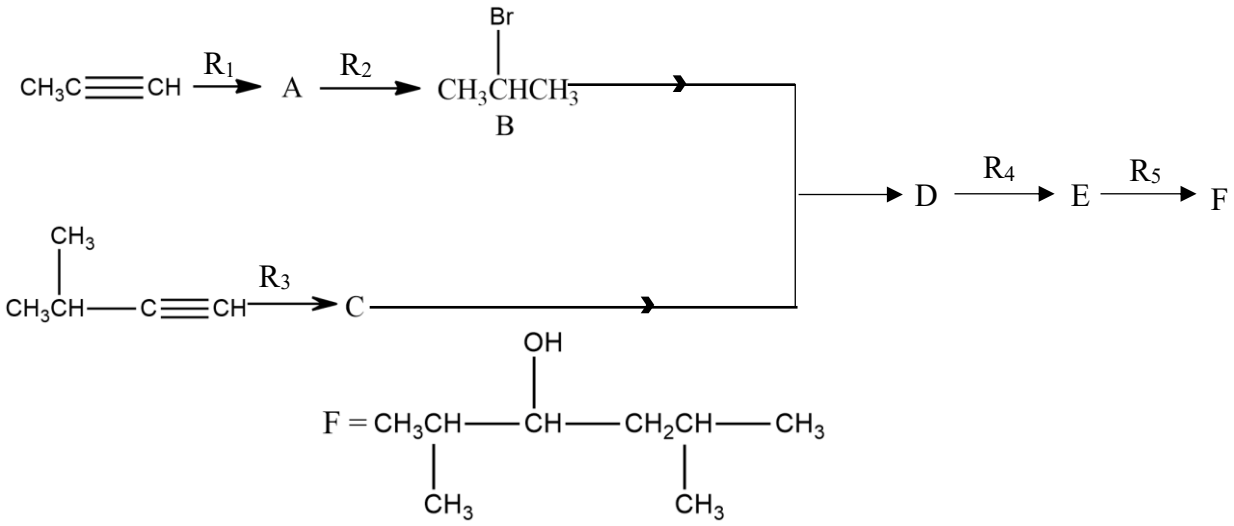
iii) Calculate the number of moles of $FeO.Cr_2O_3$ contained in 2.0 g of the sample.

iv) Calculate the mass percentage of $FeO.Cr_2O_3$ in the sample. (Fe=56, Cr=52, O=16).

8. a) Write the mechanism of the following reaction and name each major step.

$$CH_4 + Br_2 \xrightarrow{1\ mol} CH_3Br + HBr$$

b) Preparation of the compound **F** has been carried out using $CH_3C{\equiv}CH$ and $(CH_3)_2CHC{\equiv}CH$ according to the reaction scheme given below.



Give the structures of the compounds **A, C, D** and **E** and the reagents **R_1,R_2,R_3,R_4** and **R_5**.

Only chemical substances given below should be used either **singly or as combinations** as reagents.

Chemical substances: H_2, $NaNH_2$, $HgSO_4$, HBr, dil.H_2SO_4, Pd-$BaSO_4$/Quinoline catalyst, CH_3OH

c) i) Using C_2H_2 as the only starting compound, show how you would prepare compound **G** using **not** more than four (04) steps.

CH_2CH_2-C≡CH

G

ii) Give the structure of the compound **H** which is formed when compound **G** is reacted with excess Br_2.

The Periodic Table

1 **H**																2 **He**
3 **Li**	4 **Be**											5 **B**	6 **C**	7 **N**	8 **O**	9 **F**	10 **Ne**
11 **Na**	12 **Mg**											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 **K**	20 **Ca**	21 **Sc**	22 **Ti**	23 **V**	24 **Cr**	25 **Mn**	26 **Fe**	27 **Co**	28 **Ni**	29 **Cu**	30 **Zn**	31 **Ga**	32 **Ge**	33 **As**	34 **Se**	35 **Br**	36 **Kr**
37 **Rb**	38 **Sr**	39 **Y**	40 **Zr**	41 **Nb**	42 **Mo**	43 **Tc**	44 **Ru**	45 **Rh**	46 **Pd**	47 **Ag**	48 **Cd**	49 **In**	50 **Sn**	51 **Sb**	52 **Te**	53 **I**	54 **Xe**
55 **Cs**	56 **Ba**	**La-** **Lu**	72 **Hf**	73 **Ta**	74 **W**	75 **Re**	76 **Os**	77 **Ir**	78 **Pt**	79 **Au**	80 **Hg**	81 **Tl**	82 **Pb**	83 **Bi**	84 **Po**	85 **At**	86 **Rn**
87 **Fr**	88 **Ra**	**Ac-** **Lr**	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**	110 **Ds**	111 **Rg**	112 **Cn**	113 **Nh**	114 **Fl**	115 **Mc**	116 **Lb**	117 **Ts**	118 **Og**

57 **La**	58 **Ce**	59 **Pr**	60 **Nd**	61 **Pm**	62 **Sm**	63 **Eu**	64 **Gd**	65 **Tb**	66 **Dy**	67 **Ho**	68 **Er**	69 **Tm**	70 **Yb**	71 **Lu**
89 **Ac**	90 **Th**	91 **Pa**	92 **U**	93 **Np**	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	100 **Fm**	101 **Md**	102 **No**	103 **Lr**