Chemistry 2025

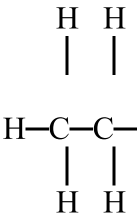
Term Paper 03

Chemistry II

Two hours

Index No: …………………………………...

* A Periodic Table is provided on last page.
* **Use of calculators is not allowed.**
* Universal gas constant, $R = 8.314\ J\ K^{-1}\ mol^{-1}$
* Avogadro constant, $N_A = 6.022 \times 10^{23}\ mol^{-1}$
* **In answering this paper, you may represent alkyl groups in a condensed manner**.

Example:  group may be shown as CH_3CH_2

PART A - Structured Essay

* Answer **all** the questions on the question paper itself.
* Write your answer in the space provided for each question. Please note that the space provided is sufficient for the answer and that extensive answers are not expected.

PART- B - Essay

* Answer **only two** questions. Use the papers supplied for this purpose.
* At the end of the time allotted for this paper, tie the answers to the two Parts A and B together so that Part A is on top and hand them over to the supervisor.
* You are permitted to remove only Parts B of the question paper from the Examination Hall.

For Examiner's Use Only

Part	Question No.	Marks
A	1	
	2	
	3	
	4	
B	5	
	6	
	7	
Total		
Percentage		

Final Mark

In Numbers	
In Letters	

Vajira N. Seneviratne PhD (Cantab)

Part A – Structured Essay

Answer **all four** questions on this paper itself. (Each question carries **100** marks)

01)

A. State whether the following statements are true or false on the dotted lines given. (reasons are not required.)

i. The first electron gain energy of N takes a positive value. …………………

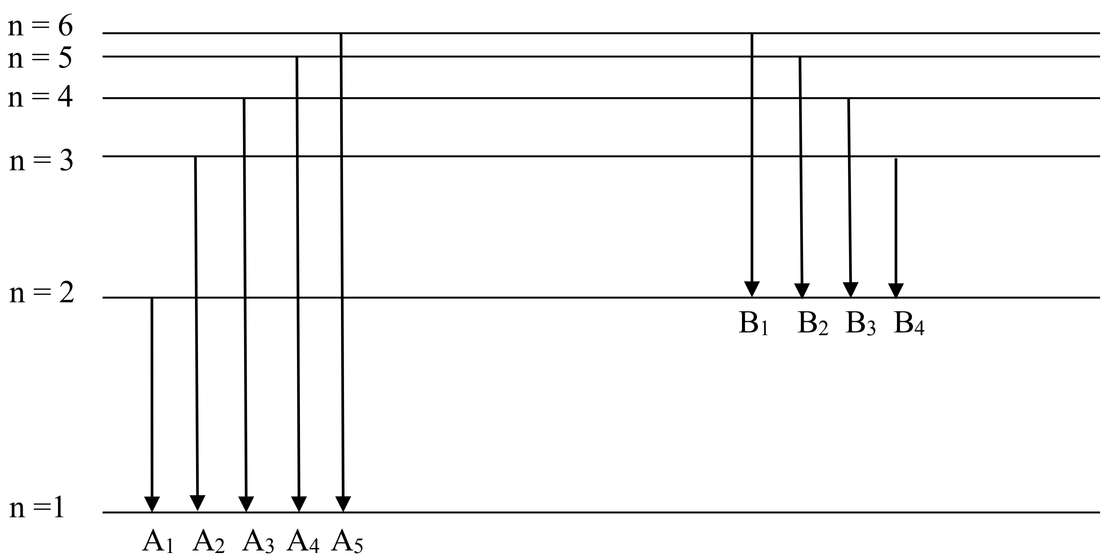
ii. All P - O bonds of H_3PO_4 acid are of the same length. …………………

iii. The effective nuclear charge acted on a valence electron of oxygen is higher than the effective nuclear charge acted on a valence electron of carbon. …………………

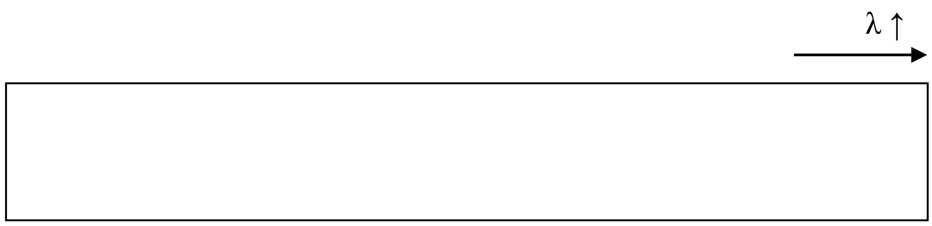
iv. The de Broglie wave length of particles of different masses travelling with the same velocities is inversely proportional to the mass of the particles. …………………

v. As the radius of the cation of an ionic compound increases, the ionic bond strength decreases. …………………

B. Shown below is the energy transmissions of electrons between few energy levels of the H emission spectrum. The wavelength corresponding to the A_1 line is 120 nm, and the wave length corresponding to the B_1 line is 400 nm. ($h = 6 \times 10^{-34}$ J S, $L = 6 \times 10^{23}$ mol^{-1})



i. Draw the emission spectrum using lines in the space given below.



ii. Name the two line series.

A series = …………………………… B series = ……………………………

iii. Calculate the energy of the A_1 line.

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C.

i. The quantum number sets of the last filed electron (n, l, m_l, m_s) of the atoms A, B, C, D, and E are given in the table below. Considering the relevant electron as the only electron present in the sub energy level of that electron, write the complete electronic configuration of these atoms in the form of $1s^2$, $2s^2$, ...

Atom	Quantum number set	Complete electronic configuration
A	4, 0, 0, +½	
B	3, 2, -2, +½	
C	2, 0, 0, +½	
D	2, 1, -1, +½	
E	3, 1, -1, -½	

ii. According to the quantum number sets of the electrons of A, B, C, D, and E atoms, arrange them in the increasing order of their energies.

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D. Arrange the following in the increasing order of their properties given in parenthesis. (Reasons are not required.)

i. CCl_4, CO_2, COS, HCHO, HCOOH (electronegativity of carbon)

…………………………………………………………………………………………

ii. CH_3^- , NH_4^+, HCHO, CNO^-, H_2S (bond angle)

…………………………………………………………………………………………

iii. CH_3-O-CH_3, CH_3CH_2OH, $CH_3CH_2NH_2$, $HOCH_2CH_2OH$ (boiling point)

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100

02)

A. The following questions are relevant to the elements of the third period of the periodic table. When answering part (i) to (vi) write the symbol of the element in the blanks given below.

i. Identify the least electronegative element. (Ignore the noble gas.)

……

ii. Identify the uni-atomic ion with the smallest size. (This ion should be stable.)

……

iii. Identify the element which has a stable configuration, although it does not have p electrons.

……

iv. Identify the element which has the highest first ionization energy, secondly.

……

v. Identify the element which forms electron-deficient compounds and exists as dimers in the gaseous state.

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B.

i. Draw the most acceptable Lewis dot-dash structure can be drawn for the ion $CH_2NO_2^-$. The skeleton of it is given below.

```
   H   O
   |   |
H – C – N – O
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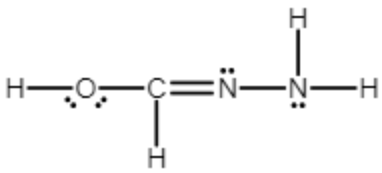
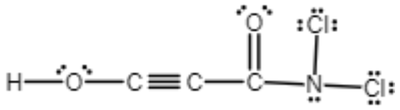
ii. The most acceptable Lewis dot-dash structure for the molecule H_3CN_2O is given below. Draw another two Lewis dot-dash structures. Write as 'unstable' under the most unstable structure which is drawn by you.



iii. By considering the Lewis dot-dash structure given below mention the followings for the atoms C, N, and O.

a. *VSEPR* pairs around atoms.
b. The electron pair geometry around the atom.
c. Shape around the atom.
d. Mention the hybridization of the atoms.
e. Mention the oxidation number of the atoms.



Atoms are numbered as follows.

$$\begin{array}{c} \qquad\qquad\qquad\qquad O^6 \\ \qquad\qquad\qquad\qquad | \\ H - O^1 - C^2 - C^3 - C^4 - N^5 - Cl \\ \qquad\qquad\qquad\qquad\qquad\qquad | \\ \qquad\qquad\qquad\qquad\qquad\qquad Cl \end{array}$$

	O^1	C^2	C^3	N^5
V*SEPR* pairs				
Electron pair geometry				
Shape				
Hybridization				
Oxidation Number				

iv. Identify the atomic / hybrid orbitals which are participated to form the following σ bonds, present in the Lewis dot dash structure of part (iii) above. [The numbering of the atoms is the same as in part (iii)]

$H – O^1$ H ………………………. O^1 ……………………….

$O^1 – C^2$ O^1 ………………………. C^2 ……………………….

$C^2 – C^3$ C^2 ………………………. C^3 ……………………….

$C^3 – C^4$ C^3 ………………………. C^4 ……………………….

$C^4 – N^5$ C^4 ………………………. N^5 ……………………….

$C^4 – O^6$ C^4 ………………………. O^6 ……………………….

v. Identify the atomic orbitals which are participated in the formation of the following π bonds present in the Lewis dot-dash structure given in above (iii). [The numbering of the atoms is the same as in the above (iii)]

$C^2 - C^3$ C^2 ………………………. C^3 ……………………….

C^4 - O^6 C^4 ………………………. O^6 ……………………….

vi.

I. What is the orientation of the two π bonds in the triple bond of the Lewis dot-dash structure in part (iii) above?

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II. Give an example for a molecule / an ion which is having a triple bond between 2 different atoms.

……………………………………………………………………………………………………

N.B. - Your example should not contain more than 3 atoms. The element present in your example should be limited to the first and second periods of the periodic table.

100

03)

A.

i. State the Dalton's law of partial pressures.

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ii. The volume of a tyre of an ordinary car is 1.0 dm^3. When there is a loss of air in the tyre, the pressure within the tyre becomes equal to the atmospheric pressure, while there will be 80% N_2 and 20% O_2 by volume. If the temperature within the tyre is 27 ºC, (1.0 atm = 1.0×10^5 Pa) calculate the total amount of moles of gas within the tyre.

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iii. In order to increase the pressure inside the tyre up to 2.5 atmosphere what is the volume of N_2 gas at 1.0 atmosphere pressure and 27 ºC that should be pumped into the tyre? When N_2 gas is pumped into the tyre the volume of the tyre increases by 10% and the final temperature reaches 37 ºC.

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iv. Calculate the mole fraction of N_2 in the tyre after N_2 was filled as in (iii) above.

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B. Complete the passage below correctly by filling each of the **26** blank spaces with the most appropriate word. **(N.B.: Each blank space should be filled with <u>one word</u> only.)**

Your choices can be (and you are free to use the **same** term more than once)
ideal, time, pressure, temperature, energy, high, real, shape, increased, varies, mean, molecules, molecular, zero, interactions, elastic, states , perfectly, random, vibrate, density, volume, molecule

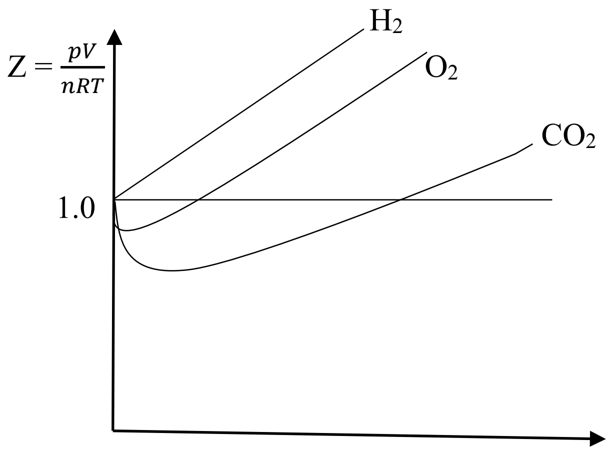
THE BEHAVIOR OF MATTER.

Solids, liquids and gases are commonly referred to as the three …………………. of matter. There is very little free space in between the particles/molecules constituting solids and liquids. At a given temperature, solids and liquids, relative to gases, therefore have a definite …………………. and a high …………………. . These two physical properties are hardly affected by (small) changes in pressure and temperature. Solids differ from liquids and gases by the presence of a definite …………………. ; constituent particles of a solid are also able to …………………. about mean positions.

According to the molecular kinetic theory of gases, gaseous molecules are in constant …………………. motion during which …………………. …………………. collisions occur. Gases that behave in this manner are referred to as ideal gases. Characteristic properties of ideal gases are the absence of …………………. between molecules and the absence of …………………. volumes. At a constant temperature, the total …………………. of the system must remain unaltered; speeds of such gas molecules can vary from approximately …………………. to very …………………. values. The variation of the distribution of molecular speeds of an ideal gas with molar mass and …………………. can be explained by means of a mathematical equation put forward in 1860 and commonly known as the Maxwell – Boltzmann distribution of molecular speeds.

The pressure, p, of an ideal gas can be calculated using the expression $3pV = mN\overline{C}^2$ where m is the mass of one …………………. and N is the number of …………………. . At a given temperature, the pressure of the gas does not vary with …………………. . Therefore the …………………. speed of molecules must remain unchanged with time at a given temperature. Although this speed …………………. with temperature, it is incorrect to say that the speeds of **all** molecules in the system are simultaneously …………………. as a result of an increase of temperature.

…………………. gases do not usually behave as ideal gases. The behavior of such gases approximates to the behavior of ideal gases at low …………………. and ………………….   ………………….
. Deviation of non-ideal gases from ideal gas behavior can be depicted by a plot of compressibility factor (Z) against …………………. as shown below.



………………….. gas

100

Vajira N. Seneviratne PhD (Cantab)

04)

A. $Na_2CO_3.5H_2O$ is provided to prepare 250 cm^3 of 1 mol dm^{-3} Na_2CO_3 solution in the laboratory. (Na = 23, C = 12, O =16, H =1)

i. Calculate the number of moles of Na_2CO_3 required.

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ii. What is the mass of $Na_2CO_3.5H_2O$ that should be weighed?

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iii. What is known as a standard solution?

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iv. What is known as a primary standard solution?

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v. Give 2 examples for the primary standards.

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vi. Calculate the volume that should be measured from the above 1 mol dm^{-3} Na_2CO_3 solution to prepare 100.00 cm^3 of 0.25 mol dm^{-3} Na_2CO_3 solution.

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B. The data which is obtained in a certain experiment by a student is given below.
125 cm^3 of 2 mol dm^{-3} dil. HNO_3 solution and 125 cm^3 of 2 mol dm^{-3} KOH solution are mixed inside a plastic cup. It is observed that the system is reached a maximum temperature of 40 ^oC. Before mixing all the solutions, they were at 27 ^oC as the initial temperature.
(Specific heat capacity of water = 4.2 J g^{-1} K^{-1} density of water = 1 g cm^{-3}).

i. Write the balanced chemical equation for the reaction between dil. HNO_3 and KOH.

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ii. Calculate the heat change (Q) for the reaction between HNO_3 and KOH.

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iii. Calculate the standard enthalpy of neutralization for the reaction between HNO_3 and KOH.

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iv. Write two assumptions that are used in this experiment.

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100

Chemistry 2025

Term Paper 03

Chemistry II

Part B-Essay

Answer **only two** questions. (Each question carries **150** marks)

Universal gas constant, R = 8.314 J K^{-1} mol^{-1} Avogadro constant, $N_A = 6.022 \times 10^{23}$ mol^{-1}

05)

A)

i. Using the following data and a thermochemical cycle, calculate the standard enthalpy of the formation of liquid benzene.

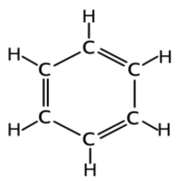
Standard enthalpy of combustion of C(s,graphite) = -393 kJ mol^{-1}
Standard enthalpy of combustion of H_2(g) = -286 kJ mol^{-1}
Standard enthalpy of combustion of C_6H_6(l) = -3262 kJ mol^{-1}

ii. Standard enthalpy of atomization of C(s,graphite) = 720 kJ mol^{-1}
Standard bond dissociation enthalpy of H_2(g) = +430 kJ mol^{-1}
Calculate the standard enthalpy change for the dissociation of 1 mol of C_6H_6(l) to gaseous atoms.

iii. The standard entropy values of C_6H_6(l), C(g), and H(g) in J mol^{-1} K^{-1} are 173, 158, and 114, respectively. Calculate the standard entropy change for the dissociation of 1 mol of C_6H_6(l) to gaseous atoms.

iv. Using the above data, calculate the minimum temperature at which 1 mol of C_6H_6(l) dissociates into gaseous atoms.

v. Standard bond dissociation enthalpy of C=C = 611 kJ mol^{-1}
Standard bond dissociation enthalpy of C-C = 346 kJ mol^{-1}
Standard bond dissociation enthalpy of C-H = 413 kJ mol^{-1}
Standard vaporization enthalpy of C_6H_6(l) = 30 kJ mol^{-1}
Using the above data, calculate the standard enthalpy change for the dissociation of 1 mol of benzene into gaseous atoms.



Benzene

vi. Indicate reasons for the difference in the answers for parts (ii) and (v) above.

Vajira N. Seneviratne PhD (Cantab)

B)

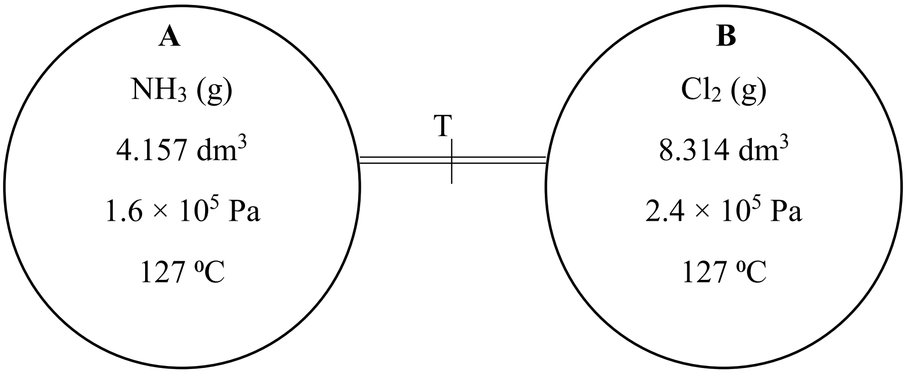
i. When 2.48 g of a mixture containing only KNO_3 and $Ca(NO_3)_2$ was subjected to complete thermal decomposition, the mass of the solid residue obtained was 1.98 g. Calculate the mass percentages of KNO_3 and $Ca(NO_3)_2$ present in the mixture.

(Ca = 40, K = 39, N = 14, O =16)

ii. Mention an observation that can be seen upon heating this mixture.

06)

A. Cl_2 gas contains in a closed rigid vessel with the volume of 8.314 dm^3 under 2.4×10^5 Pa pressure. NH_3 gas contains in another closed rigid vessel with the volume of 4.157 dm^3 under 1.6×10^5 pa pressure. Both of these vessels are kept at 127 ºC temperature and they are connected each other using a thin glass tube.



i. Calculate the number of moles of gases exist in each of the vessels separately before open the tap.

ii. The tap is opened and let both gases to mix each other. Then NH_3 and Cl_2 gases are reacted each other according to the following reaction.

$NH_3 (g) + 3Cl_2 (g) \longrightarrow NCl_3 (l) + 3 HCl (g)$

a. Calculate the total number of gaseous moles present in the vessels after completing the reaction.
b. Calculate the total pressure of the system after completing the reaction.
c. What happen to the pressure inside the system, when 0.4 mol of He (g) is added to the system without allowing the inner gases to come outside. Explain by giving reasons.
d. Calculate the final pressure in the system.

B. A solid mixture containing KIO_3, $Fe(NO_3)_3$, and an inert material. A 6.0 g sample of this mixture was dissolved in excess water to prepare a 250.00 cm^3 solution (Z).

A portion of 25.00 cm^3 from the solution (Z) and excess NaOH(aq) was added. The precipitate $Fe(OH)_3$(s) formed was heated strongly to form Fe_2O_3(s) and H_2O. The mass of the dry precipitate was 0.152 g.

A portion of 50.00 cm^3 was treated with an excess of KI(aq) and diluted H_2SO_4(aq). This solution was then diluted up to 100.00 cm^3. 25.00 cm^3 of this diluted solution was titrated with 0.10 mol dm^{-3} solution of $Na_2S_2O_3$. The burette reading of the endpoint was 13.50 cm^3.

(Fe=56, O = 16, K=39, I=127, N=14)

i. Write balanced chemical equations for the reactions occurring in the above procedure.
ii. Calculate the mass percentage of KIO_3 and $Fe(NO_3)_3$ in the above sample.
iii. What is the function of dilute H_2SO_4 in the experiment?
iv. Which of the apparatus burette, pipette, and titration flask should be rinsed with the solution to be filled into it?

07)

A. A vessel of volume 1 dm^3 has air and a small amount of water. At 25 ºC the pressure inside the vessel is 1×10^5 Nm^{-2}. When the vessel was heated up to 200 ºC, its pressure was found to be 4.6×10^5 Nm^{-2}. At 25 ºC the pressure of water vapour was negligibly small, and the volume occupied by liquid water was also negligible when compared to the volume of the container.

i. Find the number of moles of air present in the vessel at 25 ºC.
ii. Find the number of moles of water vapour at 200 ºC.
iii. Find the volume of water present in the vessel at 25 ºC. (At 25 ºC density of water is 1000 kg m^{-3})

B. Consider the following thermochemical data.

Standard molar sublimation enthalpy of Al(s)	= + 248 kJ mol^{-1}
Standard molar first ionization enthalpy of Mg(g)	= +738 kJ mol^{-1}
Standard molar second ionization enthalpy of Mg(g)	= +1451 kJ mol^{-1}
Standard molar third ionization enthalpy of Mg(g)	= + 7773 kJ mol^{-1}
Standard molar first ionization enthalpy of Al(g)	= +530 kJ mol^{-1}
Standard molar second ionization enthalpy of Al(g)	= +1750 kJ mol^{-1}
Standard molar third ionization enthalpy of Al(g)	= +1850 kJ mol^{-1}
Standard molar atomization enthalpy of Cl_2(g)	= +121 kJ mol^{-1}
Standard molar formation enthalpy of $AlCl_3$(g)	= -2154 kJ mol^{-1}
Standard molar first electron bond energy of Cl(g)	= -364 kJ mol^{-1}
Standard molar sublimation enthalpy of Mg(s)	= +148 kJ mol^{-1}
Standard molar hydration enthalpy of Mg^{2+}(g)	= -2144 kJ mol^{-1}
Standard molar hydration enthalpy of Al^{3+}(g)	= -3252 kJ mol^{-1}

i. Calculate and show the standard molar lattice dissociation enthalpy of $AlCl_3$(g).
ii. Thereby calculate the formation enthalpy of the hypothetical compound $MgCl_3$(g).
Explain its stability.
iii. Using only necessary data of all given above, calculate the enthalpy change of the reaction below.

$$2Al^{3+}(aq) + 3Mg(s) \longrightarrow 3Mg^{2+}(aq) + 2Al(s)$$

C. A solution is prepared by dissolving 200 mg of a sample of impure $KMnO_4$ in 100 cm^3 of H_2O. 15 cm^3 of 0.02 mol dm^{-3} acidified oxalate [$C_2O_4^{2-}$] solution is consumed to titrate 25 cm^3 of the above solution. Calculate the mass percentage of $KMnO_4$ present in the above $KMnO_4$ sample.
(K=39, Mn=55, O=16, C=12)

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**