Index No.:_____ AM 06/I.18s

L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2018 SECOND SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	I
DATE:	3rd September 2018
TIME:	9:00 a.m. to 12:05 p.m.

Required Data: Relative atomic masses: H = 1; C = 12; N = 14; O = 16; Fe = 56
The universial gas constant, R = 8.314 J K^{-1} mol^{-1}

Answer ALL questions

1. a) The major isotope of nitrogen has an atomic number of 7 and a nucleon number of 14. Explain the following terms:

i) atomic number _____

_____ (1)

ii) nucleon number _____

_____ (1)

iii) isotope _____

_____ (1)

b) Give the full electronic configuration of a ground state nitrogen atom in terms of spdf notation and use an electrons-in-boxes diagram to describe the way in which electrons are arranged in a ground state nitrogen atom.

_____

_____

_____

_____

_____ (4)

c) The first ionisation energies of four consecutive elements are as follows:

Element	B	C	N	O
1st IE / kJ mol^{-1}	801	1086	1402	1314

Explain the trend(s) observed in these values.

(2)

d) Nitrogen-14 is transformed to Carbon-14 in the upper atmosphere by the nucleus capturing a neutron. Then, Carbon-14 decays back to Nitrogen-14. Write equations representing both nuclear reactions.

(2)

(Total: 11 marks)

2. Explain each of the following observations relating to bonding and intermolecular forces.

a) Aluminium has a higher melting point than sodium.

(3)

b) The average bond energy term of a C=C double bond is less than twice that of a C-C single bond.

(3)

c) Both iodine and diamond contain covalent bonds. However, iodine can be converted into a vapour at a much lower temperature than diamond.

(3)

d) The carbon to carbon bonds in buta-1,3-diene are all equivalent in length.

(3)

(Total: 12 marks)

Questions continue on next page

3. Ethanol is a widely used solvent in household and industrial settings. It can be manufactured by the direct hydration of ethene using a phosphoric(V) acid catalyst. The reaction involved is as follows:

$$CH_2{=}CH_2\,(g) + H_2O\,(g) \rightleftharpoons CH_3CH_2OH\,(g) \qquad \Delta H^{\ominus} = -46\ kJ\ mol^{-1}$$

a) Write an equation for the equilibrium consant, K_p for the reaction above and state the units of the constant.

(2)

b) State, with reasoning, what effect, an increase in pressure at constant temperature will have on the equilibrium.

(1)

c) State, with reasoning, what effect, an increase in temperature at constant pressure will have on the equilibrium.

(1)

d) Phosphoric(V) acid acts as a heterogeneous catalyst in the process mentioned above. Explain the term heterogeneous catalyst and state, with reasons, what effect the phosphoric(V) acid has on the rate of the reaction and the equilibrium yield.

(3)

e) Using the standard enthalpy change for the reaction above and the standard enthalpy of formation of the reactants given below, calculate the standard enthalpy of formation of gaseous ethanol.

Compound	$\Delta H_f^{\ominus}$ **/ kJ mol^{-1}**
CH_2CH_2 (g)	+52.3
H_2O (g)	–242

(3)

f) Ethene can be made in a laboratory experiment through the dehydration of ethanol by passing vapour of the alcohol over an aluminium oxide catalyst. What is the volume of gaseous ethene that can be collected from the dehydration of 4.0 g of ethanol at a laboratory temperature of 300 K, assuming that the reaction has a 100% yield?

(3)

(Total: 13 marks)

4. This question is about the chemistry of sulfur and its compounds.

a) Name **TWO** allotropes of sulfur.

(1)

Question continues on next page

b) Complete the following table:

Experiment	**Observations**	**Chemical equation**
Addition of barium chloride solution to sodium sulfate(VI) solution.		
Addition of concentrated sulfuric(VI) acid to solid sodium bromide.		
Addition of concentrated sulfuric(VI) acid to solid glucose, $C_6H_{12}O_6$.		
Addition of dilute hydrochloric acid to sodium thiosulfate.		

(8)

(Total: 9 marks)

5. a) Iron is extracted from iron(III) oxide by the high temperature process summarised by the equation below.

F_2O_3 (s) + 3 CO (g) $\rightarrow$ 2 Fe (s) + 3 CO_2 (g)

The following thermodynamic data at 298 K relate.

$\Delta H^{\ominus}$ / kJ mol^{-1}	−23
$\Delta S^{\ominus}$ / J K^{-1} mol^{-1}	+9

i) Calculate the standard free energy change for the reaction at 298 K.

_____

_____ (2)

ii) Explain why this reaction is feasible at all temperatures.

_____

_____ (2)

iii) Explain why despite the fact that this reaction is feasible at all temperatures, the extraction is carried out at high temperatures.

(1)

b) A 1.00 g sample of an iron ore was completely dissolved in dilute sulfuric(VI) acid and all the iron reduced to iron(II). The acidified iron(II) solution was transferred to a 100 cm^3 volumetric flask and filled up to volume. A 25.00 cm^3 sample of the solution required 7.00 cm^3 of 0.0200 M potassium manganate(VII) solution to reach the end-point. Calculate the percentage of iron in the ore.

(5)

c) Consider the half reaction

$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$ $\quad E^\ominus = -0.44$ V

Explain why the value of $E^\ominus$ suggests that iron will react with an aqueous solution of an acid to give Fe^{2+} ions and hydrogen gas.

(3)

(Total: 13 marks)

6. Consider the following hydrides which have various degrees of solubility in water.

NaH HCl NH_3 H_2S CH_4

a) State which of the hydrides is least soluble in water and explain why.

(2)

b) Using chemical equations, explain which hydrides dissolve in water to give a pH different than that of pure water.

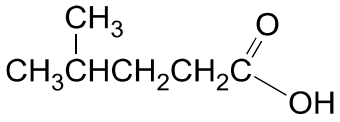
(4)

c) NH_3 and CH_4 both have 4 electron pairs around the central atom but the H–N–H bond angle and the H–C–H bond angle are different. Explain this statement.

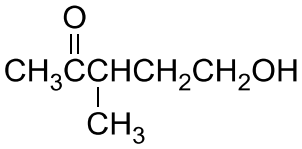
(4)

(Total: 10 marks)

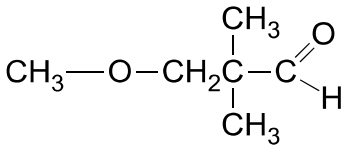
7. This question is about isomers of some of the compounds with molecular formula $C_6H_{12}O_2$. Four compounds with this formula are shown below.



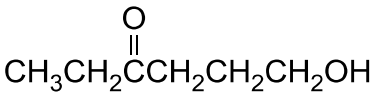
A



B



C



D

a) Give the systematic name of isomer A.

_____ (1)

b) Draw an ester which is an isomer of the compounds A to D. (1)

c) Identify which compound can exhibit optical isomerism and indicate the chiral carbon in the molecule by labelling with an asterisk (*). (2)

Question continues on next page

d) The compounds A, B, C and D were tested using a number of reagents. Complete the following table. (6)

e)

Reagent(s)	**Observation in the case of a positive reaction**	**Compound(s) that would give a positive result**
Na_2CO_3		
I_2, NaOH		
$[Ag(NH_3)_2]^+$		

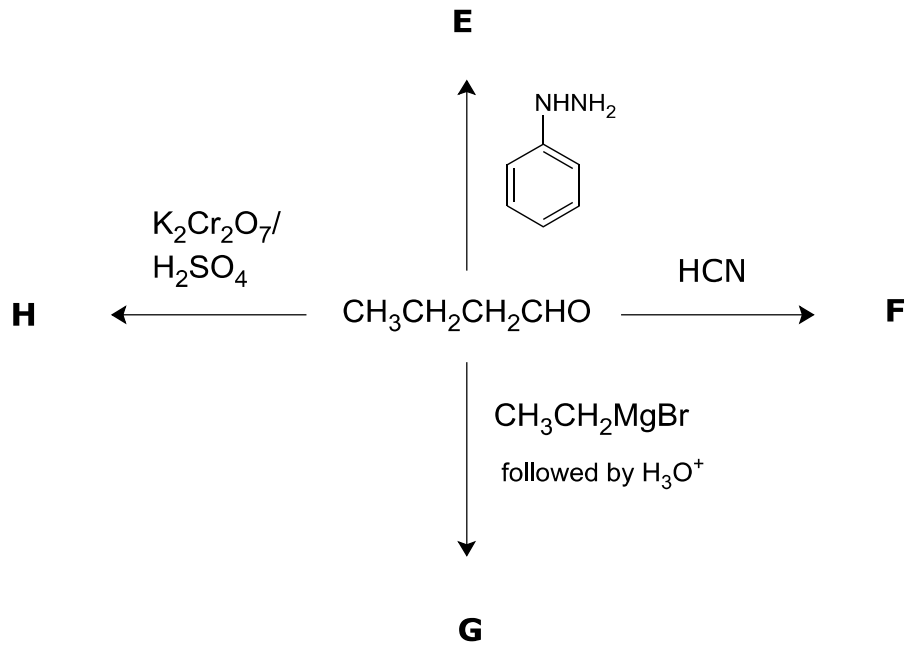
f) The infra-red spectrum of compound A has absorption bands corresponding to the energy required to stretch the C=O, C–O and O–H bonds. Given that the bond energies are in the order O–H > C=O > C–O, assign the following wave number values to the respective bonds in the molecule: 1700 cm^{-1}, 3000 cm^{-1}, 1210 cm^{-1}.

_____

_____ (2)

(Total: 12 marks)

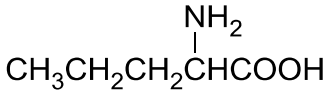
8. Consider the following reaction scheme involving butanal.



a) Draw structural formulae for substances E, F, G and H. (6)

E =
F =
G =
H =

b) Explain, using relevant chemical equations, how compound I can be produced from product F. (4)

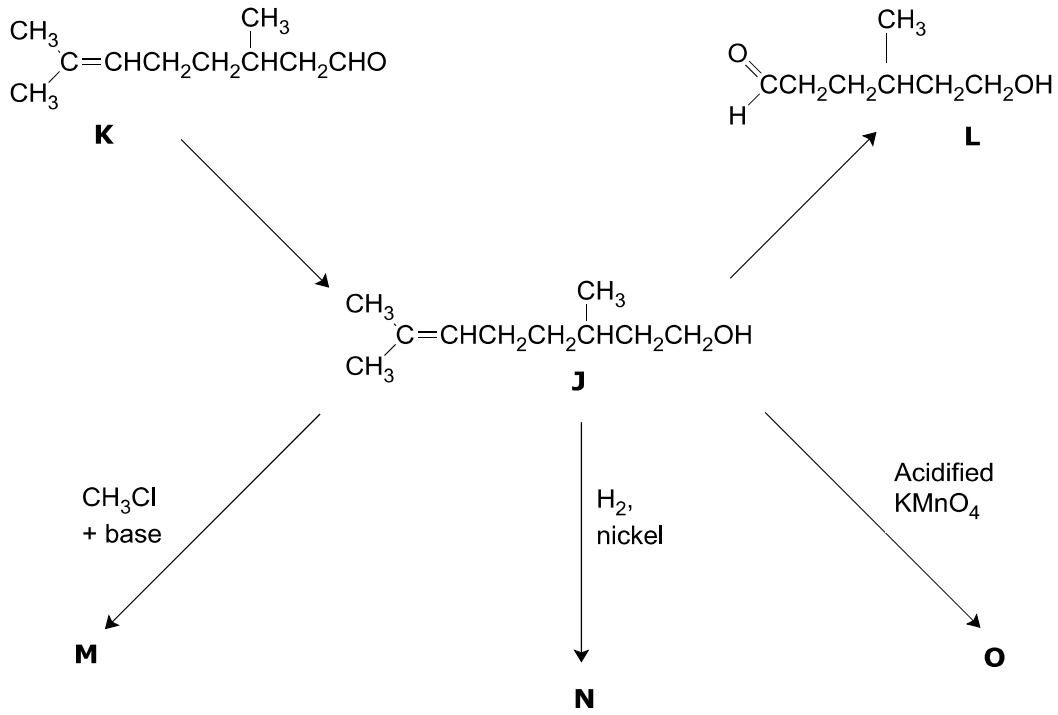


I

(Total: 10 marks)

Questions continue on next page

9. (–)-Citronellol, J, is a compound found in roses. Consider the following reaction scheme.



a) State the reactants and conditions that can be used:

i) to produce J from K;

_____

_____ (2)

ii) to produce L from J.

_____

_____ (2)

b) Draw structural formulae for substances M, N and O obtained from citronellol, J. (6)

M =
N =
O =

(Total: 10 marks)

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MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2018 SECOND SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	II
DATE:	4th September 2018
TIME:	9:00 a.m. to 12:05 p.m.

A Periodic Table is provided.

Answer TWO questions from each section and ANY other question.

SECTION A

1) a) At 298 K, the acid dissociation constant of benzoic acid is 6.3×10^{-5} mol dm^{-3}. Calculate the pH and pOH of a 1×10^{-3} mol dm^{-3} aqueous solution of the acid and the degree of dissociation of the acid at this concentration. (10)

b) Calculate the pH of a solution prepared by adding 5×10^{-3} moles of sodium benzoate to 100 cm^3 of the solution in part (a). (6)

c) Explain why phenolphthalein is a better indicator than methyl orange for the titration of benzoic acid solution with sodium hydroxide solution. (4)

(Total: 20 marks)

2) a) The initial rate of chemical reactions can be used to write the rate equation of a chemical reaction.

i) Explain how the initial rate of a reaction can be measured from the variation of the concentration of a reactant during a chemical reaction. (3)

ii) Explain how one can use the initial rate data to determine the rate equation of a chemical reaction. (3)

b) The rate equation for the gas-phase reaction

$$NO_2\,(g) + CO\,(g) \rightarrow NO\,(g) + CO_2\,(g)$$

is given by rate = $k[NO_2]$ which is not as may be expected from the stoichiometry of the reaction. Suggest a reason for this observation. (4)

c) Explain why reaction rates are increased by an increase in temperature and the addition of a catalyst. (5)

d) Explain why a catalyst for the following reactions will be useful for the environment. (5)

$$2\,NO \rightarrow N_2 + O_2$$
$$2\,CO + O_2 \rightarrow CO_2$$

(Total: 20 marks)

3) Write explanatory notes, giving chemical equations where appropriate, on each of the following statements.

a) The decomposition of lithium nitrate(V), like that of magnesium nitrate(V) yields two gases whilst that of other group 1 nitrate(V) compounds only yields one gas. (5)

b) The reaction of magnesium with water is energetically favourable but kinetically unfavourable. (5)

c) Fluorine gas reacts with water to give only one fluorine containing acid however, chlorine gas reacts to give two chlorine containing acids. (5)

d) Chlorides of carbon, silicon and lead react differently with water. (5)

(Total: 20 marks)

4) a) Give three examples of transition elements and use their electronic configurations and common oxidation states to illustrate why these elements belong to this category. (7)

b) Transition metal ions can form complex ions.

i) By drawing the structure of a suitable octahedral complex ion, explain the terms complex ion and monodentate ligand. (3)

ii) The complex compound with the formula $Pt(NH_3)_2Cl_2$ has a square planar arrangement. Explain how this complex compound exhibits geometric isomerism. (4)

iii) Explain how the complex ion of iron(III) with ethanedioate having composition $[Fe(C_2O_4)_3]^{3-}$ exhibits optical isomerism. (4)

iv) Describe a chemical test that can be used to distinguish between the following two isomers: $[Cr(H_2O)_3Cl_3].3H_2O$ and $[Cr(H_2O)_4Cl_2]Cl.2H_2O$. (2)

(Total: 20 marks)

SECTION B

5) a) A polymer is found to have 54.54% carbon, 9.10% hydrogen and 36.36% oxygen. Find the empirical formula of the polymer and deduce the structure of the repeat unit of this polymer. (5)

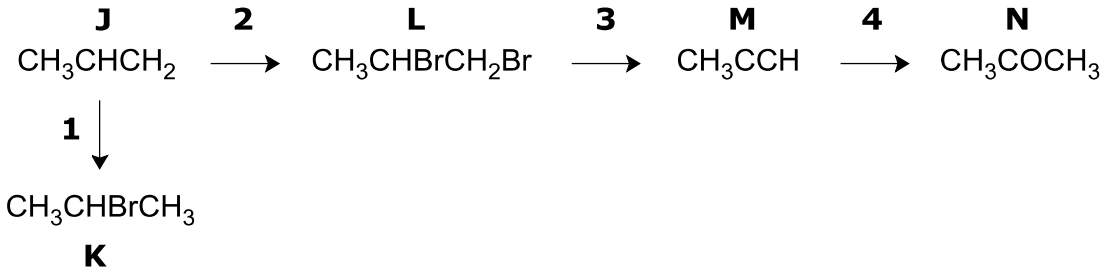
b) A sample of mass 1 g of the polymer dissolved in 100 cm^3 of water gave an osmotic pressure of 1238 N m^{-2} at 298 K. Calculate the molar mass of the polymer and hence the number of repeat units in a polymer chain. (R= 8.314 Nm K^{-1} mol^{-1} (10)

c) Explain what is meant by reverse osmosis and describe the importance of this technique to Malta. (5)

(Total: 20 marks)

6) This question concerns the chemistry of propene (J) and its products.

a) Consider the following reaction scheme.



i) Give the reagents and conditions for reactions 1, 2, 3 and 4. (4)

ii) Write out mechanisms for reactions 1 and 2 and explain why K is the most abundant product in reaction 1. (5)

iii) A mass spectrum of product L gives three peaks which are considered as the molecular ion peaks at m/z 200, 202 and 204 in the ratio of 1:2:1. Given that bromine exists as two isotopes 79 and 81 g mol^{-1} in equal proportions, explain this observation. (4)

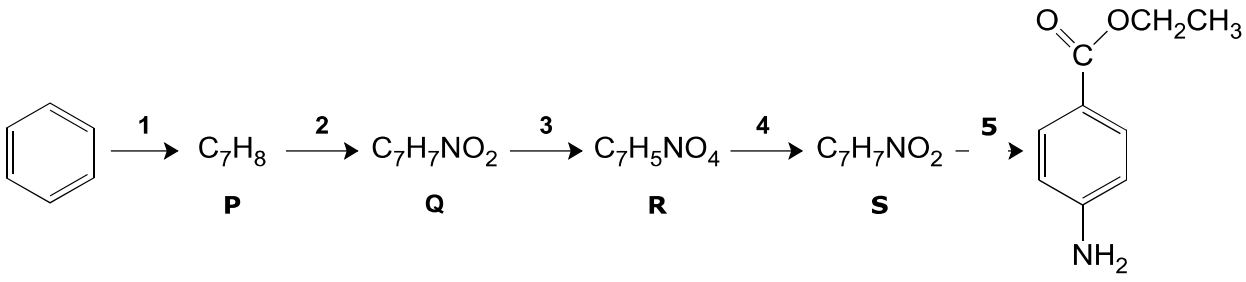
iv) The terminal hydrogen of compound M is said to be acidic. Give a reaction that shows this property of the compound. (3)

b) Propene is the monomer used in the production of polypropene. The latter has been the cause of environmental problems. Explain the chemical basis of this concern and give two examples of how the problem can be reduced. (4)

(Total: 20 marks)

Questions continue on next page

7) Benzocaine is local anaesthetic and can be produced from benzene according to the synthetic pathway shown below.



Benzocaine

a) Give the reactions and conditions for steps 1, 2, 3, 4 and 5 and draw the structures of P, Q, R and S. (14)

b) Step 2 produces two isomers and only one is used for steps 3 to 5. Draw the structure of the unused isomer and state which of the two isomers produced is the most abundant. (2)

c) Benzocaine is hardly soluble in water; however it is highly soluble in acidic aqueous solutions. Explain this observation and suggest how storing benzocaine in acidic media can affect its long-term stability. (4)

(Total: 20 marks)

8) Ethanal, ethanol and methanol have the following properties.

Compound	ethanal	ethanol	methoxymethane
RMM / g mol^{-1}	44	46	46
Boiling point / °C	20.2	78.4	−24.0

a) Explain why the variation in boiling points is so large considering the similarity in RMM. (4)

b) Mixtures of ethanol and ethanal exhibit negative deviations from Raoult's Law.
i) Explain what is meant by negative deviations from Raoult's Law. (2)
ii) Explain why this behaviour occurs for mixtures of these compounds. (2)
iii) Sketch a T-X diagram for mixtures of these compounds. (3)

c) Describe how ethoxyethane can be prepared from ethanol using inorganic reagents. (4)

d) Describe the reaction of ethanal with sodium hydroxide and how this differs from the reaction of benzaldehyde with sodium hydroxide. (5)

(Total: 20 marks)

Index No.:_____ AM 06/III.18s

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MATRICULATION AND SECONDARY EDUCATION CERTIFICATE
EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2018 SECOND SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	III – *Practical*
DATE:	30th August 2018
TIME:	3 hours 5 minutes

1. You are provided with the following solutions:

   i) a solution of sodium hydroxide labelled A_n, where n is the candidate laboratory number;
   ii) a solution of 0.0600 mol dm^{-3} ethanedioic acid labelled B;
   iii) a solution of ethanoic acid C.

   You are required to determine:

   i) the molar concentration of the sodium hydroxide in solution A_n;
   ii) the molar concentration of a solution of ethanoic acid;
   iii) the dissociation constant of ethanoic acid.

a) Record the value of your laboratory number, n (found on solution A), on your answer book in the following box.

CANDIDATE LABORATORY NUMBER, n:.....

Determination of the molar concentration of sodium hydroxide in solution A_n

b) Using a pipette, transfer 25.0 cm^3 of solution A_n into a 250 cm^3 volumetric flask and make up to the mark with distilled water.

c) Fill the burette with the diluted alkali solution. Transfer 25.0 cm^3 of solution B into a conical flask and titrate with the diluted alkali solution using phenolphthalein as indicator.

Report your results in the table below, recording **ONE** approximate and **TWO** accurate titrations. (18)

Initial burette reading			
Final burette reading			
Titre (cm^3)			

Mean titre: _____ cm^3 of diluted sodium hydroxide solution

DO NOT WRITE ABOVE THIS LINE

d) Calculate the molar concentration of the sodium hydroxide solution A_n to 3 sig. figures.

(4)

Determination of the concentration of ethanoic acid.

e) By means of a pipette transfer 25.0 cm^3 of solution C into a conical flask and titrate with the diluted alkali solution, using phenolphthalein as indicator. Report your results in the table below, recording **ONE** approximate and **TWO** accurate titrations. (18)

Initial burette reading			
Final burette reading			
Titre			

Mean titre: _____ cm^3 diluted sodium hydroxide solution

DO NOT WRITE ABOVE THIS LINE

f) Calculate the concentration of ethanoic acid in solution C.

(4)

Determination of the pK_a of ethanoic acid.

For ethanoic acid we can write

$$CH_3COOH\ (aq) + H_2O\ (l) \rightleftharpoons CH_3COO^-\ (aq) + H_3O^+\ (aq)$$

The acid dissociation constant for this process is given by

$$K_a = \frac{\left[H_3O^+\right]\left[CH_3COO^-\right]}{\left[CH_3COOH\right]}$$

Thus when $[CH_3COOH] = [CH_3COO^-]$, $K_a = [H_3O^+]$ and pK_a = pH of the solution. Therefore, if the solution of ethanoic acid is treated with exactly one half of the amount of strong base, eg. sodium hydroxide, required for complete neutralisation, the pH of the mixture at this point is equal to the pK_a of ethanoic acid.

Question continues on next page

g) To 25.0 cm^3 of solution C in a conical flask add exactly one half of the amount of diluted sodium hydroxide solution as was required in part (f) for complete neutralisation. Using the pH indicator paper provided, find the pH of the resultant mixture.

pH of resultant mixture = _____ (5)

Hence pK_a = _____ (1)

(Total: 50 marks)

2) You are provided with two salts labelled D and L. Carry out the tests as described below. Record your observations and inferences in the spaces provided. Suggest the possible identities of the two salts.

a) Clean a nichrome wire with concentrated hydrochloric acid and carry out a flame test on substance D. (3)

Observation	*Inference*

b) Dissolve about 0.5 g of D in about 5 cm^3 of distilled water. Retain for tests c and h. (3)

Observation	*Inference*

c) Add and shake 2 cm^3 of dilute sulfuric acid to 2 cm^3 of solution obtained in test b. Retain this solution for test d. (3)

Observation	*Inference*

DO NOT WRITE ABOVE THIS LINE

d) To the solution obtained in test c, add about 0.5 g of zinc powder and shake. (3)

Observation	*Inference*

e) Dissolve about 1 g of substance L in 5 cm^3 of distilled water. Retain for tests f and h. (3)

Observation	*Inference*

f) To about 1 cm^3 of solution from test e, add dilute sodium hydroxide solution dropwise, until in excess. (3)

Observation	*Inference*

g) To about 1 cm^3 of solution from test e, add aqueous ammonia dropwise, until in excess. (3)

Observation	*Inference*

Question continues on next page

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h) To about 1 cm^3 of solution from test e, add a few drops of the solution obtained in test b. (3)

Observation	*Inference*

i) Add a few drops of concentrated sulfuric acid to about 0.1 g of substance L. Heat vigourously, remove test tube from Bunsen burner and carefully note the odour. **(CARE!)** (3)

Observation	*Inference*

Hence suggest possible cations and anions that may be present in D and L. (2)

Cations: _____ and _____

Anions: _____ and _____

(Total: 29 marks)

3. You are provided with an organic solid labeled G. Carry out tests as described below and propose a plausible identity for the substance. (4)

a) Burn about 0.2 g of G on a crucible lid.

Observation	*Inference*

DO NOT WRITE ABOVE THIS LINE

b) Place about 0.2 g of G in a test tube, add about 4 cm^3 of water and shake. Then add aqueous sodium hydroxide. (4)

Observation	*Inference*

c) To about 0.5 g of substance G, add around 5 cm^3 of water and shake. Test with litmus paper. (4)

Observation	*Inference*

d) Dissolve about 0.2 g of G in about 5 cm^3 of ethanol. Then add bromine water dropwise. (4)

Observation	*Inference*

e) In a dry test-tube, place 0.5 g of G, 0.5 cm^3 of ethanol and 2 drops of concentrated sulfuric acid. Heat in a boiling water bath for about 2 minutes. Tip the contents into 10 cm^3 of 10% sodium hydrogencarbonate solution and carefully note the odour. (4)

Observation	*Inference*

Question continues on next page

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Suggest a possible structure for compound G. (1)

G is possibly: _____

(Total: 21 marks)