MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2016

SUBJECT:	CHEMISTRY
PAPER NUMBER:	I
DATE:	2nd September 2016
TIME:	9.00 a.m. to 12.05 p.m.

Required Data: Molar mass (g mol^{-1}): H = 1 C = 12 O = 16
Ideal Gas Constant, R = 8.314 J K^{-1} mol^{-1}

Answer all questions

1. (a) The atomic number of carbon is 6.
   (i) Write the ground state electronic configuration of carbon in sp notation.

_____

_____

   (ii) Write the ground state electronic configuration of carbon as an electrons-in-boxes diagram.

_____

_____

(2 marks)

(b) Draw the electronic configuration of the three states of hybridisation of carbon as an electrons-in-boxes diagram. Only the electrons in the outer shell are needed.
   (i) sp

_____

_____

   (ii) sp^2

_____

_____

   (iii) sp^3

_____

_____

(iv) In each of the three cases, name a compound where the type of hybridisation is present.

sp _____

sp^2 _____

sp^3 _____

(6 marks)

(c) When carbon is sp^3 hybrised it forms one type of bond, while when it is sp^2 or sp hybridised it forms two kinds of bond. Explain briefly.

_____

_____

_____

_____

(2 marks)
(Total = 10 marks)

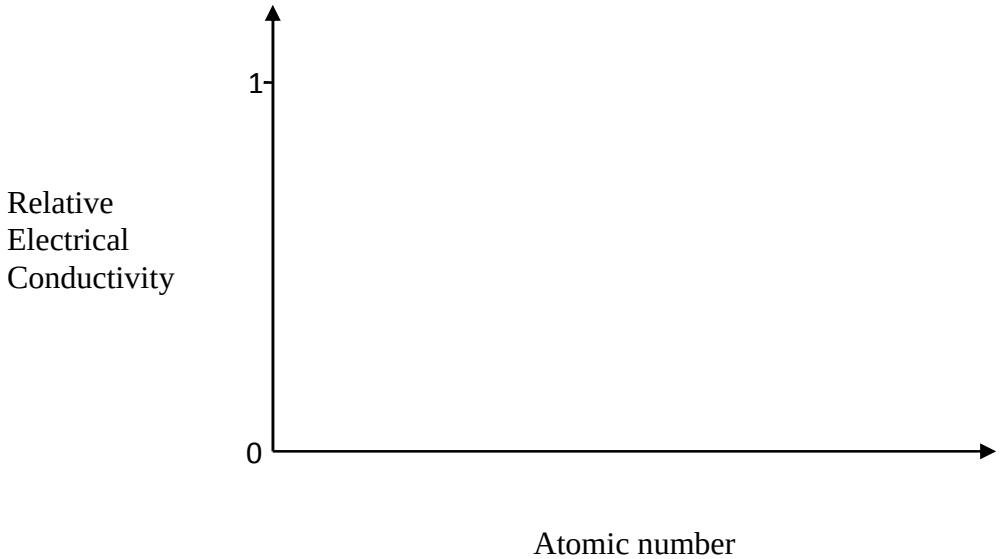
2. (a) The periodic behaviour of the properties of elements can be illustrated by trends in both physical and chemical properties.

(i) Vertical trends can be found down a group of the periodic table. Mention TWO other types of trends that can be found in the periodic table.

_____

_____

(ii) Consider electrical conductivity and illustrate by sketching a graph on the axes below, to show how electrical conductivity changes across the period for the elements of period 3 in their standard state.



(4 marks)

(b) (i) Consider the following elements in period 2. Fill in the blank spaces in the Table as required.

Element	Li	Be	C	N	O	F
Formula of hydride					H_2O	
Physical state at 25 ^oC and 1 atm					liquid	

(ii) Consider the first four elements of the period. Fill in the blanks as required.

Element	Na	Mg	Al	Si
Formula of chloride	NaCl			
Type of structure	Giant ionic			

(8 marks)
(Total = 12 marks)

3. This question is about gas laws.

(a) (i) Gas A occupies a volume of 1000 cm^3 at a pressure of 10^5 Pa and a temperature of 27 ^oC. Assuming that it behaves as an ideal gas, and that its mass is 1.12 g, find its relative molecular mass.

(ii) Gas A reacts with cold concentrated sulfuric acid forming an addition product. The addition product can then be hydrolysed into alcohol. Suggest the molecular formula for gas A, explaining your answer with chemical equations.

(7 marks)

(b) (i) Define Dalton's law of partial pressures.

(ii) The total pressure of a mixture of two gases, X and Y, is 250 Pa. The mixture is made up of 3 moles of X and 2 moles of Y. Find the partial pressure of each gas in the mixture.

(4 marks)
(Total = 11 marks)

4. (a) Methyl orange is a pH indicator with a Ka value of 3.39×10^{-4} mol dm^{-3}.

(i) What is the function of an indicator during an acid-base titration?

(ii) Calculate the pH at which the concentrations of the two forms of the indicator that give different colours are equal.

(iii) Use your answer to part (a) (ii) to explain why methyl orange cannot be used as an indicator in a weak acid - strong base titration.

(6 marks)

(b) The value of the solubility product of barium sulfate at 25 ^{o}C is 1.1 x 10^{-10}.

(i) Write the expression for the solubility product and indicate its units.

(ii) Find the solubility of barium sulfate at 25 ^{o}C.

(iii) Find the concentration of barium ions in solution if a 0.20 mol dm^{-3} sulfuric acid solution is added to a saturated solution of barium sulfate.

(5 marks)
(Total = 11 marks)

5. This question is about the hydrogen halides.

(a) Hydrogen chloride can be prepared by the reaction of an ionic chloride with concentrated sulfuric acid. However, reaction of the acid with an ionic bromide produces side products. Explain.

(2 marks)

(b) Name one acid that can be used to produce hydrogen bromide from an ionic bromide without the formation of side products.

(1 mark)

(c) Sketch a graph showing the boiling points of the hydrogen halides as one moves down group 7. Explain this trend in terms of intermolecular bonding.

(4 marks)

(d) Hydrofluoric acid is a weaker acid than hydrochloric acid. Explain.

(3 marks)
(Total = 10 marks)

6. (a) Consider the following reaction:

$$BrO_3^- + 5Br^- + 6H^+ \longrightarrow 3Br_2 + 3H_2O$$

A set of experiments was performed to investigate the effect on the initial rate of reaction on changing the concentration of one reactant while keeping constant that of other reactants. The experimental data is reported in the Table below:

Experiment	**$[BrO_3^-]$** (mol dm^{-3})	**$[Br^-]$** (moldm^{-3})	**pH**	**Initial Rate** (mol $dm^{-3}s^{-1}$)
A	0.15	0.15	0.82	8.0×10^{-4}
B	0.30	0.15	0.82	1.6×10^{-3}
C	0.30	0.30	0.82	3.2×10^{-3}
D	0.15	0.15	0.52	3.2×10^{-3}

(i) Considering the experimental data, deduce the rate equation for the reaction. Show your reasoning.

(ii) Find the overall order of reaction.

(iii) From the information above, deduce, giving a reason, whether the reaction takes place in a single elementary step or via a multistep mechanism.

(7 marks)

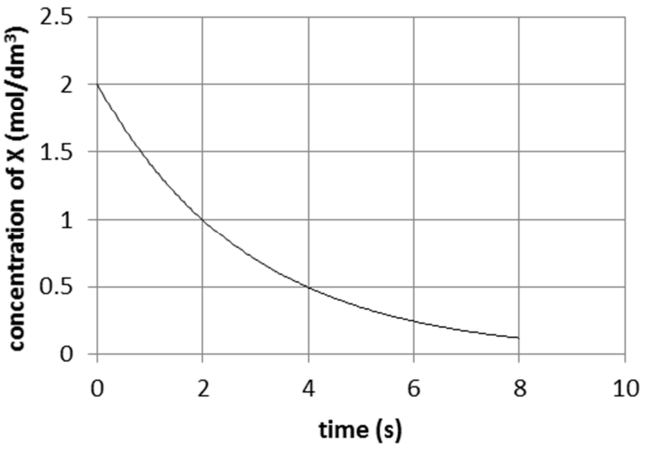
(b) The rate constant k is related to the activation energy and the temperature through the Arrhenius equation: $k = Ae^{\frac{-Ea}{RT}}$

(i) Explain qualitatively the relationship of k with E_a and T respectively.

(ii) What is the term *A* called?

(3 marks)

(c) For the reaction X →products, the following plot shows the change of concentration of X with time.

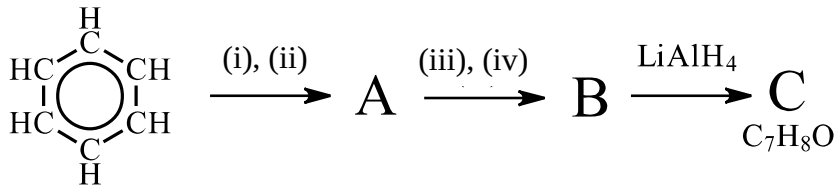


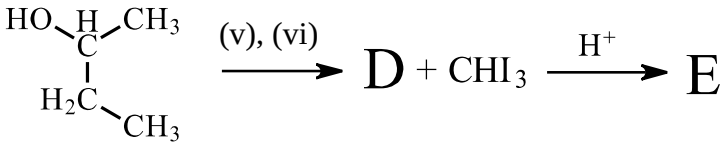
(i) Find the half-life for this reaction. Show your working.

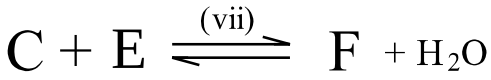
(ii) Use the graph to determine the order of reaction.

(4 marks)
(Total = 14 marks)

7. Complete the scheme below by identifying organic compounds **A** to **F** and reagents (i) to (vii).







A: _____ **B**: _____

C: _____ **D**: _____

E: _____ **F:** _____

(6 marks)

(i): _____ (ii): _____ (iii): _____

(iv): _____ (v): _____ (vi): _____

(vii): _____

(6 marks)
(Total = 12 marks)

8. (a) Addition of ozone to hydrocarbon **G** followed by hydrolysis in the presence of zinc dust results in one product, 6-oxoheptanal. Identify hydrocarbon **G** and explain your answer.

(5 marks)

(b) What will the major product, compound **H**, be if hydrogen bromide is allowed to react with hydrocarbon **G**?
NOTE: *If you do not know the answer to part (a) continue the question using propene instead of hydrocarbon* ***G****.*

(1 mark)

(c) Using compound **H** as a starting point, give a reaction showing the production of an alcohol.

(1 mark)

(d) Name and give the mechanism for reaction in part (c).

(3 marks)
(Total = 10 marks)

9. **I** is an aliphatic organic compound having **one** functional group and **three** carbon atoms.

(a) Addition of aqueous HNO_2 to compound **I** results in the evolution of nitrogen gas. Deduce the possible functionalities of compound **I**. Explain and give chemical equations where possible.

(6 marks)

(b) No apparent reaction is observed when dilute NaOH is added to compound **I**. Deduce the functionality of compound **I**. Explain and give chemical equations where possible.

_____

_____

_____

_____

_____

(3 marks)

(c) From the information obtained in parts (a) and (b) give the systematic name of compound **I**.

_____

(1 mark)
(Total = 10 marks)

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MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2016

SUBJECT:	CHEMISTRY
PAPER NUMBER:	II
DATE:	3rd September 2016
TIME:	9.00 a.m. to 12.05 p.m.

A Periodic Table is provided.
Ideal Gas Constant, R = 8.314 J K^{-1} mol^{-1}
1.0 atm = 101 325 Pa
Faraday constant = 96 500 C mol^{-1}

Answer two questions from each section and any other question.

Section A

1. This question is about the chemistry of transition metals.

(a) (i) Give systematic names for the following complexes:
A - $[Cr(H_2O)_4Cl_2]^-$
B - $[Fe(H_2O)_2(C_2O_4)_2]^-$
C - $[Fe(C_2O_4)_3]^{3-}$

(ii) Give the coordination number of the metal in complexes **A** and **B**.

(4 marks)

(b) Explain in detail the following statements giving chemical equations and/or chemical structures where appropriate:
(i) Complex **A** exhibits stereoisomerism;
(ii) Complex **C** is more stable than complex **B**.

(10 marks)

(c) Copper reacts differently with different concentrations of nitric(V) acid. Explain this statement giving relevant chemical equations.

(6 marks)
(Total = 20 marks)

2. (a) Consider the equilibrium reaction:

$$XY_{2\,(g)} \rightleftharpoons X_{(g)} + 2Y_{(g)}$$

(i) Write the expression for Kp for the equilibrium reaction. Indicate its units in atm, if any.
(ii) Write an expression for the number of moles at equilibrium of XY_2, X and Y.
(iii) If the total pressure of the equilibrium mixture is P, give an expression for the partial pressures of XY_2, X and Y at equilibrium.

(9 marks)

(b) Ammonia can be produced by an exothermic reaction in the Haber Process.
(i) Give an equation for the production of ammonia in the Haber Process and include the conditions for the reaction in this process.
(ii) Explain how and why compromise conditions for temperature are required for this process.

(7 marks)

(c) Give a balanced chemical equation to show the behaviour of ammonia as a:
(i) Brønsted-Lowry base;
(ii) ligand.

(4 marks)
(Total = 20 marks)

3. (a) Consider these half reactions and their respective standard electrode potentials:

$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$ $\quad E^o = -0.41V$
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$ $\quad E^o = -2.38V$

(i) Draw the cell diagram for a galvanic cell made up of the Fe^{2+}/Fe and Mg^{2+}/Mg electrodes.
(ii) Find the E^o value of the cell given in part (a) (i).
(iii) Deduce the polarity of the cell.
(iv) Give the redox reaction that takes place in the galvanic cell. Show your reasoning.
(v) Calculate the free energy change for the spontaneous reaction given in part (a) (iv).

(13 marks)

(b) The Nernst equation for the following general reaction at 25 ^oC is:

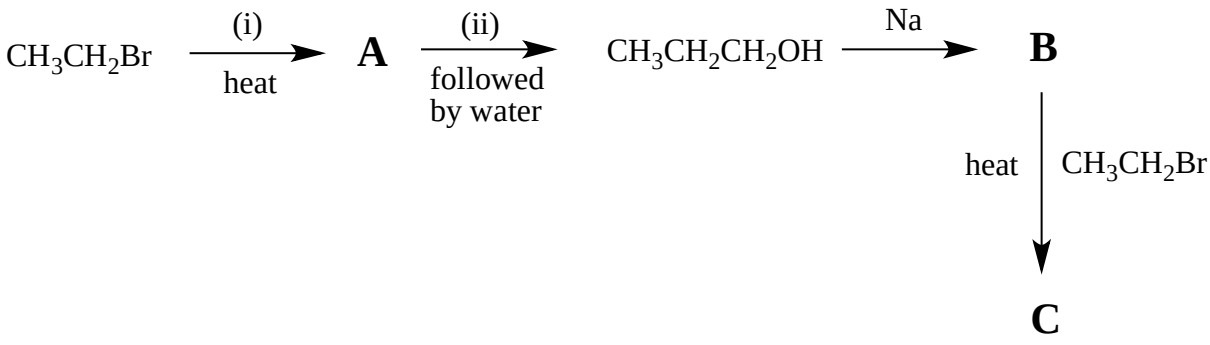
$$aA + bB \rightleftharpoons cC + dD$$

$$E = E^o - \frac{0.059}{n} \log_{10} \left(\frac{[C]^c[D]^d}{[A]^a[B]^b} \right)$$

(i) Write the Nernst equation for reaction given in part (a) (iv).
(ii) Find the electrode potential for the reaction if the concentrations of the $Fe^{2+}(aq)$ and the $Mg^{2+}(aq)$ solutions are 2.50 mol dm^{-3} and 0.125 mol dm^{-3} respectively.
(iii) Explain whether the reaction is more or less thermodynamically feasible at the concentrations given in part (b) (ii), than at standard conditions.

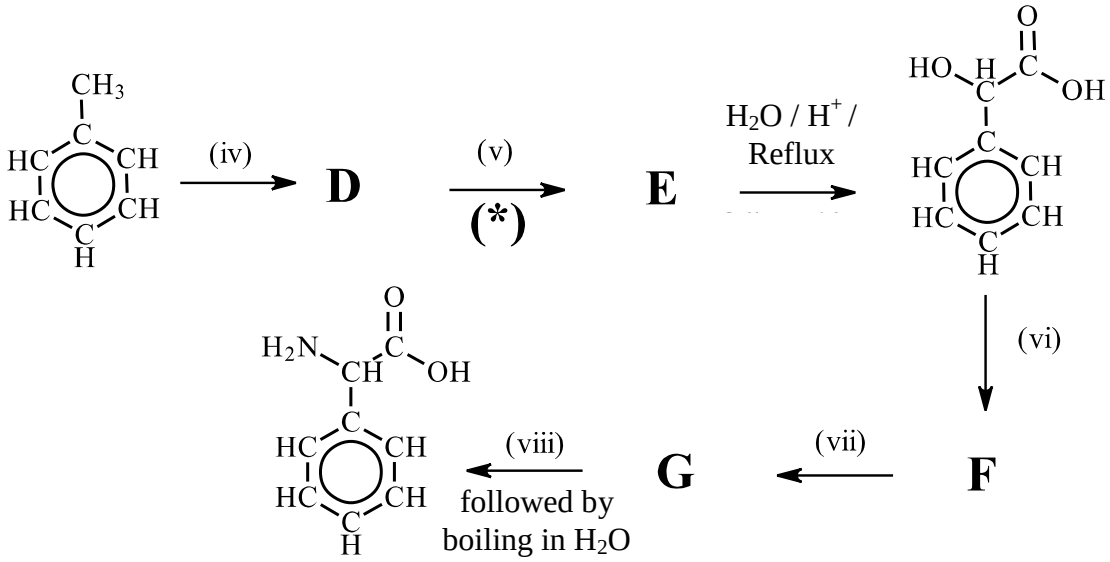
(7 marks)
(Total = 20 marks)

4. (a) Complete the following scheme by identifying organic compounds **A** to **C** and reagents (i) and (ii). Only the organic products are shown in this scheme.



(5 marks)

(b) Complete the following scheme by identifying organic compounds **D** to **G** and reagents (iv) to (viii). In your answer, you should also identify and give the mechanism for the step marked by **(*)**.



(15 marks)
(Total = 20 marks)

Section B

5. (a) Give the mechanism for the nitration of benzene. In your answer also state the temperature at which this reaction is expected to proceed.

(5 marks)

(b) Explain the reactivity of halogenoalkanes for substitution reactions in terms of their structure and the halogen atom.

(5 marks)

(c) Methanoic acid reacts in an anomalous behaviour when compared to other carboxylic acids. Discuss using the reactions with PCl_5 and acidified permanganate as an example.

(5 marks)

(d) Butan-1-ol and butan-2-ol are structural isomers giving different products when they react with oxidizing agents. One of these isomers can also exhibit stereoisomerism. Discuss.

(5 marks)
(Total = 20 marks)

6. This question is about s and p-block chemistry.

(a) Lithium and magnesium exhibit a diagonal relationship. Explain the reasons for this diagonal relationship, and give TWO chemical properties to illustrate the relation.

(6 marks)

(b) (i) Indicate which elements in Group I have peroxides and superoxides and draw the structures of these anions.
(ii) Explain why not all the members of Group I form peroxides or superoxides.
(iii) Give the equation and the experimental conditions for the preparation of a Group I superoxide.

(8 marks)

(c) Consider the following standard electrode potentials:

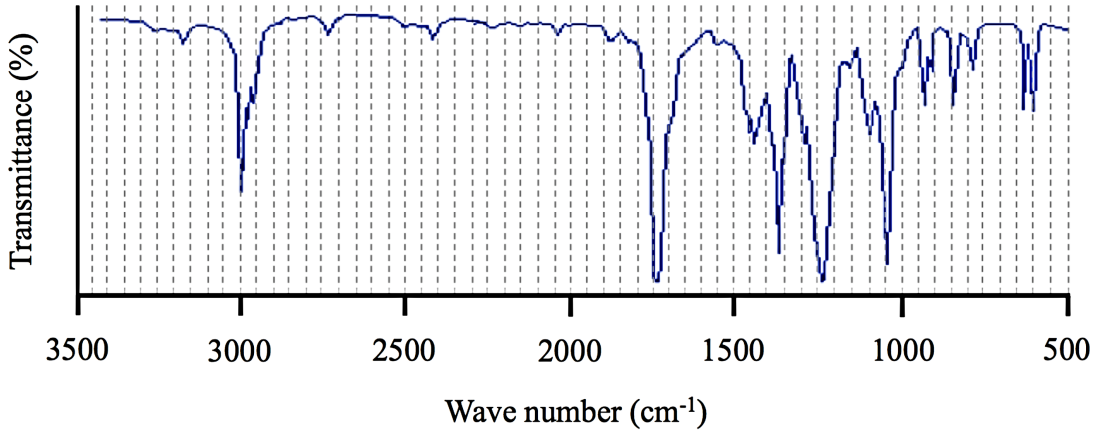
$Pb^{4+} + 2e^- \rightarrow Pb^{2+}$ $\quad E^o = +1.69$ V
$I_2 + 2e^- \rightarrow 2I^-$ $\quad E^o = +0.54$ V
$Sn^{4+} + 2e^- \rightarrow Sn^{2+}$ $\quad E^o = +0.13$ V

Use this information to explain the stability and redox character of simple compounds of Sn(II) and Pb(IV) in Group 4.

(6 marks)
(Total: 20 marks)

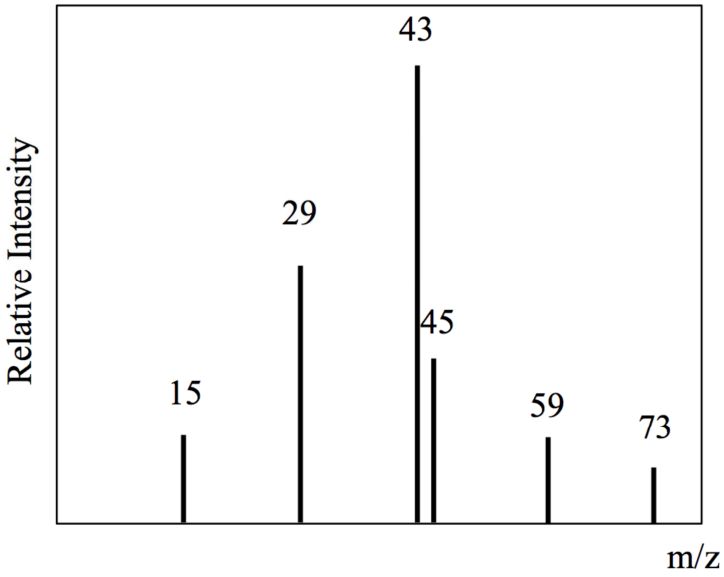
7. This question is about organic compound **A**. The IR spectrum and a partial mass spectrum of compound **A** are given below. Note that the parent peak in the partial mass spectrum is **not** shown.

Heating 0.15 g of compound **A** to 80 ^{o}C at a pressure of 1.0 atm, results in a vapour that occupies 49.37 cm^{3}.



Functional Group		Characteristic Absorptions (cm^{-1})	Notes
Carboxylic Acid	C=O	1700-1725	Strong absorption
	O-H	2500-3300	Strong absorption, very broad band
	C-O	1210-1320	Strong absorption
Amide	C=O	1640-1690	Strong absorption
	N-H	3100-3500	Unsubstituted have two bands
Ester	C=O	1735-1750	Strong absorption
	C-O	1000-1300	Two bands or more

Note, that this table shows only bond stretches.



(a) From the above information, and knowing that compound **A** has only one functional group, deduce the structure of organic compound **A**. In your answer, you should determine all the mass spectrum peaks.

(13 marks)

(b) Describe in detail how a pure sample of compound **A** can be prepared in the laboratory. (No diagrams are required)

(7 marks)

(Total: 20 marks)

8. This question is about thermodynamics. The data needed to answer this question is given below.

Standard enthalpy changes **(kJ mol^{-1})**

$\Delta H^o_{\text{atomisation}}$ (Na)	107
$\Delta H^o_{\text{bond enthalpy}}$ (F_2)	153
$\Delta H^o_{\text{first ionization enthalpy}}$ (Na)	496
$\Delta H^o_{\text{lattice enthalpy}}$ (NaF)	-923
$\Delta H^o_{\text{first electron affinity}}$ (F)	-328

Standard entropy values **(J mol^{-1} K^{-1})**

Substance	$Na_{(s)}$	$F_{2\,(g)}$	$NaF_{(s)}$
S^o (J mol^{-1} K^{-1})	51.2	202.7	51.5

(a) Define the terms *standard enthalpy of formation* and *standard enthalpy of atomization*.

(3 marks)

(b) Calculate the standard enthalpy of formation of sodium fluoride. Your answer should include all relevant calculation steps including any cycle / cycles required.

(7 marks)

(c) (i) Calculate the standard change in entropy for the system defined by the equation:

$$Na_{(s)} + \frac{1}{2}F_{2\,(g)} \longrightarrow NaF_{(s)}$$

(ii) Explain the relation between entropy and spontaneity of a reaction and determine whether the formation of sodium fluoride from its elements is expected to be spontaneous or not at 25 ^oC.

(10 marks)

(Total: 20 marks)

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UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2016

SUBJECT:	CHEMISTRY
PAPER NUMBER:	III – *Practical*
DATE:	29th August 2016
TIME:	3 hours 5 min

There are three questions in this paper. Answer all questions.

1. In this experiment you are required to identify the metal cation of an ethanedioate salt.

You are supplied with the following chemicals:
(i) 125 cm^3 solution of hydrochloric acid of concentration **1.00 mol dm^{-3}** labelled **A**.
(ii) 150 cm^3 of a solution of sodium hydroxide labelled $\mathbf{B_n}$ where **n** is the candidate laboratory number.
(iii) 75 cm^3 **1.00 mol dm^{-3}** ethanoic acid labelled **E**.
(iv) Phenolphthalein indicator

(a) Enter the value of your laboratory number, **n**, in the following box.

CANDIDATE LABORATORY NUMBER, n:.....

Standardisation of sodium hydroxide solution, B_n.

(b) Pipette 25.0 cm^3 of solution **A** into a conical flask followed by three drops of phenolphthalein indicator. Titrate with $\mathbf{B_n}$ from the burette. Enter your titration results in the table below.

	1st Titration	2nd Titration	3rd Titration
Initial burette reading (cm^3)			
Final burette reading (cm^3)			
Titre (cm^3)			

Mean titre : _____ cm^3 of $\mathbf{B_n}$

(20 marks)

(c) Calculate the concentration of sodium hydroxide solution, $\mathbf{B_n}$.

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$$

(3 marks)

Calculating the enthalpy change of reaction for a strong base and a weak acid.

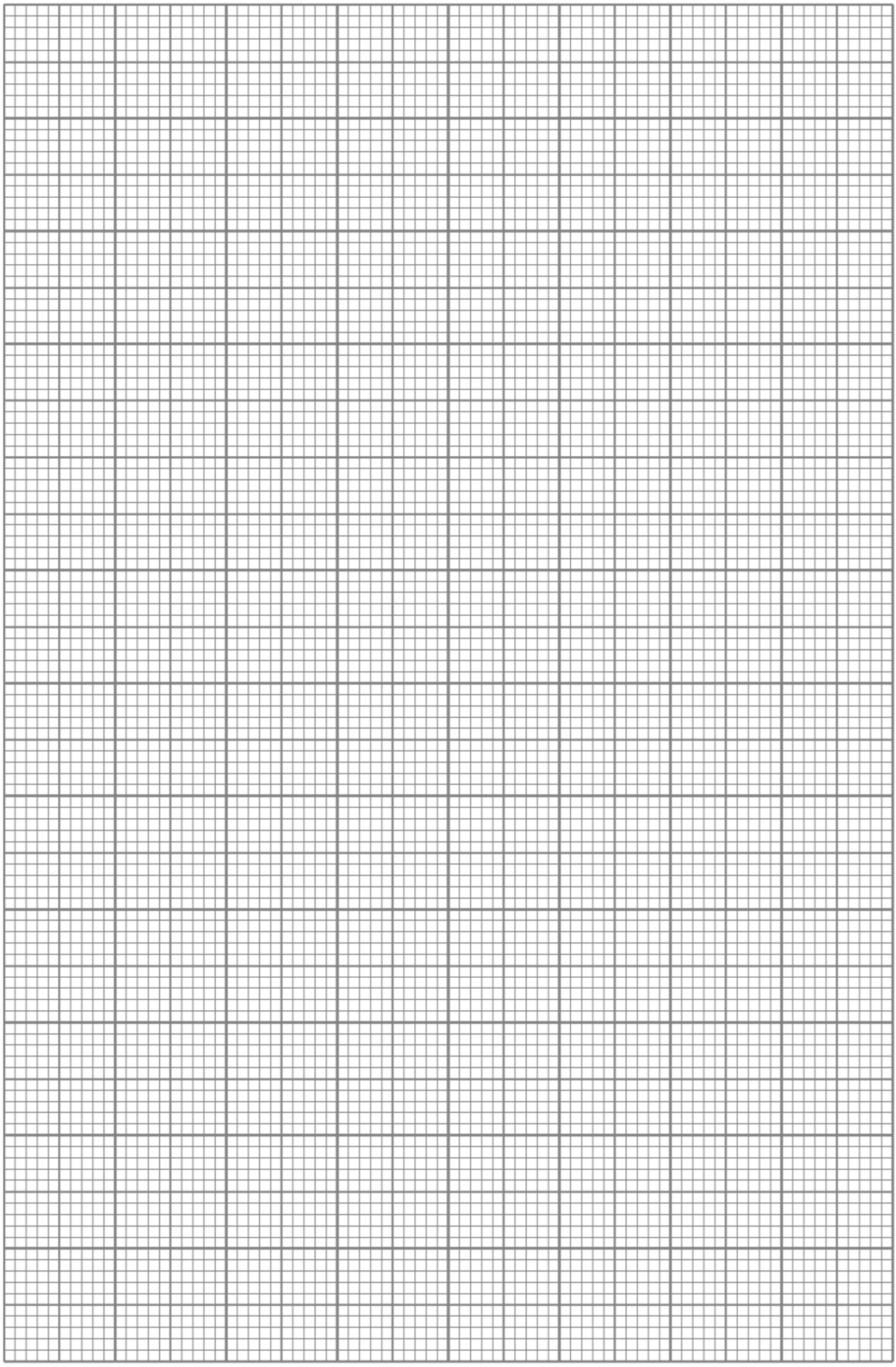
(d) Insert a dry polystyrene cup into a 250 cm^3 beaker to prevent spilling the cup and pipette 25.0 cm^3 of solution **E** into the dry polystyrene cup. Start taking temperature readings of this solution (to the nearest 0.1 ^oC) and record the temperature at half-minute intervals for 3 minutes.

At 3.5 minutes from the start miss out the temperature reading and using the **pre-filled burette** with sodium hydroxide solution, $\mathbf{B_n}$ transfer 30.0 cm^3 of solution. Continue taking temperature readings at half-minute intervals up to 10 minute with constant stirring.

Time (minutes)	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Temperature (^oC)											

Time (minutes)	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
Temperature (^oC)										

Plot a graph of temperature against time and calculate the temperature change resulting from the neutralisation reaction.



Final temperature (^{o}C)	
Initial temperature (^{o}C)	
Temperature change (^{o}C), ΔT	

(20 marks)

(e) Given that

$$\mathbf{q = -mc\Delta T}$$

where **m** is the mass of the solution whose density is assumed to be 1.0 g cm^{-3} and **c** is the specific heat capacity of the solution approximated to 4.18 J g^{-1} K^{-1} ,calculate the enthalpy change for the reaction, **q**.

(3 marks)

(f) Calculate the **standard** enthalpy change, ΔH, for the reaction.

(4 marks)

2. You are provided with an inorganic substance, solid **X** and solution **Y**. Carry out the tests as described below, record your observations carefully and attempt to identify the compounds.

(a) Dissolve a small amount (tip of a spatula) of **X** in approximately 20 cm^3 of water. ***Retain this solution for tests (b) to (e) and (i)***.

(b) To about 1 cm^3 of the solution from (a), add aqueous sodium hydroxide slowly until in excess.

Observation	*Inference*

(c) To about 1 cm^3 of the solution from (a), add ammonia solution slowly until in excess.

Observation	*Inference*

(d) To about 1 cm^3 of the solution from (a), add 1 cm^3 dilute sulfuric acid.

Observation	*Inference*

(e) To about 1 cm^3 of the solution from (a), add 1 cm^3 of dilute nitric acid followed by an equal amount of silver nitrate solution. Add ammonia solution until in excess (at least 4 cm^3).

Observation *Inference*

(f) Carry out a flame test on solid **X**.

Observation *Inference*

(g) To about 1 cm^3 of solution **Y**, add aqueous sodium hydroxide slowly until in excess.

Observation *Inference*

(h) To about 1 cm^3 of solution **Y**, add ammonia solution slowly until in excess.

Observation *Inference*

(i) To about 1 cm^3 of solution **Y**, add 1cm^3 of the solution from (a) followed by 1 cm^3 of dilute nitric acid.

Observation	*Inference*
_____	_____
_____	_____
_____	_____
_____	_____

Conclusion

Substance **X** is probably: _____

Substance **Y** is probably: _____

(30 marks)

3. You are provided with an organic liquid, substance **Z**, containing more than one functional group. Perform the following tests on **Z** and record your observations and inferences in the spaces provided.

(a) Burn a **small quantity (two drops)** of **Z** on a crucible lid. Do not allow the flame to burn for longer than you need to make a good observation.

Observation	*Inference*

(b) Test a sample of liquid **Z** with litmus paper.

Observation	*Inference*

(c) To 1 cm^3 of 2,4-dinitrophenylhydrazine (2,4-DNPH) solution add few drops of liquid **Z**.

Observation	*Inference*

(d) To 1 cm^3 of silver nitrate solution add 2 drops of aqueous sodium hydroxide. Add ammonia solution slowly until the brown precipitate dissolves followed by a few drops of liquid Z.

Observation	*Inference*
_____	_____
_____	_____
_____	_____
_____	_____

(e) To three drops of concentrated sulfuric acid (CARE! CORROSIVE) add 1 cm^3 of glacial ethanoic acid and 1 cm^3 of **Z** and heat the mixture in a boiling water bath for 1 minute. Cool and add the mixture to 10 cm^3 of sodium carbonate solution.

Observation	*Inference*
_____	_____
_____	_____
_____	_____
_____	_____

(f) To 1 cm^3 of iodine solution add 5 drops of dilute sodium hydroxide solution. The solution becomes faint yellow in colour. To the resultant solution add 5 drops of liquid **Z** and shake gently.

Observation	*Inference*
_____	_____
_____	_____
_____	_____
_____	_____

Conclusion: A possible structure for **Z** is: _____

(20 marks)

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