MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2014

SUBJECT:	CHEMISTRY
PAPER NUMBER:	I
DATE:	2nd September 2014
TIME:	9.00 a.m. to 12.00 noon

Required Data: **Molar Mass / g mol^{-1} : H = 1, C = 12, N = 14, O = 16, S = 32, Ca = 40**
Avogadro's Number = 6.02 × 10^{23} mol^{-1}

Answer all questions

1. (a) Define the term *atomic number* of an element.

_____

_____

(2 marks)

(b) Give the symbol, including mass number and atomic number, for a neutral atom of an element which contains 20 neutrons and 19 electrons.

_____

(2 marks)

(c) Using s and p notation, give the electronic configuration of the atom in part (b).

_____

(1 mark)

(d) Define the term *relative* atomic mass of an element.

_____

_____

(2 marks)

(e) Explain how ions of different mass are differentiated in a mass spectrometer.

_____

_____

(2 marks)

(f) The atom in part (b) is one isotope of the element. Mass spectrometry of the element gave the following data:

m/z	39.0	41.0
Relative abundance	93.3	6.7

Calculate the relative atomic mass of the element.

(3 marks)
(Total = 12 marks)

2. (a) Define the term *electronegativity*.

(2 marks)

(b) Explain what is meant by the following types of bonds and give an example of each type of bond.

(i) a *polar covalent bond;*

(2 marks)

(ii) a *hydrogen bond.*

(2 marks)

DO NOT WRITE ABOVE THIS LINE

(c) Using *VSEPR* theory, predict the shapes and bond angles of molecules of NH_3 and BF_3 and explain why the molecules have different polarities.

(4 marks)

(Total = 10 marks)

3. Consider the formation of dinitrogen tetroxide from nitrogen dioxide.

$$N_2O_4\ (g) \rightleftharpoons 2NO_2\ (g) \qquad \Delta H^{\ominus} = +57.2\ kJ\ mol^{-1}$$

(a) Explain qualitatively what would happen if an equilibrium mixture of $NO_2(g)$ and $N_2O_4(g)$ was subjected to:

(i) halve the pressure, whilst the temperature was kept constant and equilibrium was re-established.

(2 marks)

(ii) an increase in temperature, whilst pressure was kept constant and equilibrium was re-established.

(2 marks)

(b) (i) Write an expression for K_p of the reaction.

(1 marks)

(ii) A flask is initially charged with 3.00 atm of dinitrogen tetroxide gas and 2.00 atm of nitrogen dioxide gas at 25°C and allowed to reach equilibrium. It was found that the partial pressure of nitrogen dioxide decreased by 0.952 atm. Estimate the value of K_p for this system:

(3 marks)

(Total = 8 marks)

4. Sulfamic acid is a white solid with the following composition:

Element	Hydrogen	Nitrogen	Oxygen	Sulfur
% by mass	3.09	14.42	49.43	33.06

(a) (i) Deduce the empirical formula of sulfamic acid.

(2 marks)

(ii) The molar mass of sulfamic acid is 97.1 g mol^{-1}. Use this information to deduce the molecular formula of sulfamic acid.

(1 mark)

(b) A solution containing 5.5×10^{-3} moles of sulfamic acid reacts with excess magnesium to produce 66 cm^3 hydrogen gas at room temperature and pressure.

(i) Calculate the number of moles of hydrogen gas produced in this reaction. (The volume of 1 mole of a gas is 24 dm^3 mol^{-1} at room temperature and pressure)

(1 mark)

(ii) Show that the data confirms that sulfamic acid is a monoprotic acid.

(3 marks)

(c) Sulfamic acid can be bought from hardware stores to descale kettles. The inside of a kettle is coated with 9.53 g of calcium carbonate. The volume of water required to cover the scale in the kettle is 200 cm^3. Calculate the minimum concentration of sulfamic acid required to remove the scale.

(3 marks)
(Total = 10 marks)

5. This question concerns the oxides and hydrides of the elements in the third period (Na – Cl).

(a) In the table below give the formula of one oxide of each of the elements and indicate the nature of the bonding in each.

	Na	Mg	Al	Si	P	S	Cl
Oxides							
Nature of bonding							

(7 marks)

(b) How do the structures of the oxides vary from left to right across the period?

(2 marks)

DO NOT WRITE ABOVE THIS LINE

(c) An oxide of one of the elements in the period is said to be amphoteric. Identify the oxide and give balanced equations that show its amphoteric nature.

(3 marks)

(d) Write an equation for the action of sodium hydride on water.

(1 mark)

(e) *In aqueous solution, hydrogen sulfide and hydrogen chloride act as a weak acid and a strong acid respectively.* Explain this statement.

(2 marks)
(Total = 15 marks)

6. The carbonates and nitrates of Group 2 metals decompose when heated.

(a) Calcium oxide is produced by the thermal decomposition of calcium carbonate.

(i) Write the equation for the decomposition reaction.

(1 mark)

(ii) The decomposition is an endothermic process. Explain using the concepts of free energy and entropy why this process occurs on heating but not at room temperature.

(3 marks)

DO NOT WRITE ABOVE THIS LINE

(iii) Explain why the decomposition temperature of calcium carbonate is much lower than that of barium carbonate.

(3 marks)

(b) The thermal decomposition of barium nitrate occurs according to the following equation

$$2Ba(NO_3)_2(s) \longrightarrow 2BaO(s) + 4NO_2(g) + O_2(g)$$

(i) Explain why this decomposition reaction is a redox process.

(3 marks)

(ii) Given the enthalpy changes of formation in the table below, calculate the enthalpy change of the thermal decomposition of barium nitrate.

compound	ΔH_f / kJ mol^{-1}
$Ba(NO_3)_2$	–992
BaO	–558
$NO_2(g)$	+33

(3 marks)

(Total = 13 marks)

DO NOT WRITE ABOVE THIS LINE

---

7. Write a chemical equation, showing any catalyst required, representing each of the following changes: *(All parts carry equal marks.)*

(a) the formation of ethene from ethanol;

(b) the conversion of an alkyne into a ketone;

(c) an aldol reaction;

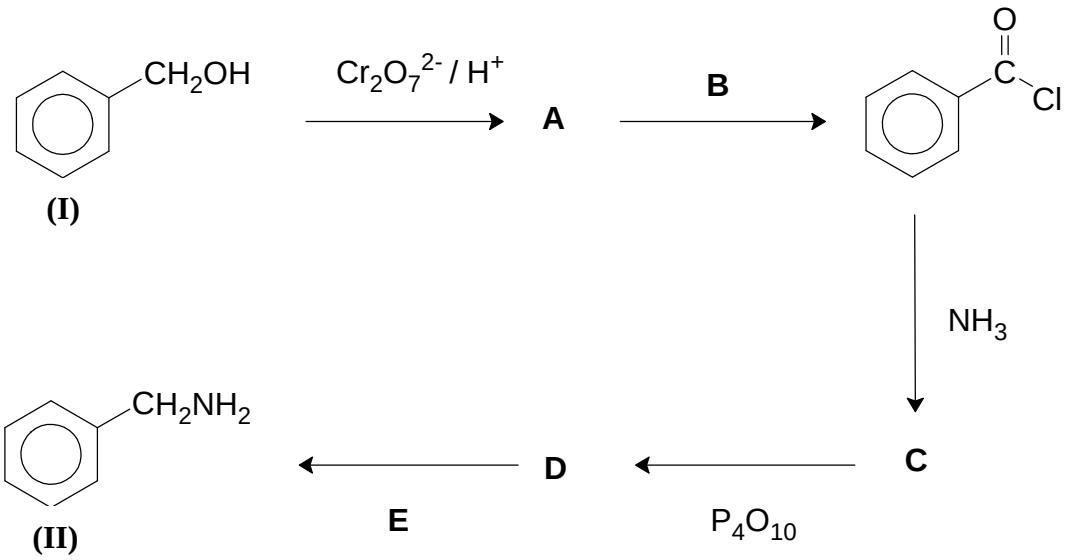
(d) a Cannizzaro reaction;

(e) a Hofmann degradation reaction.

(Total = 10 marks)

DO NOT WRITE ABOVE THIS LINE

8. Consider the following reaction scheme.



(a) Identify the compounds and reagents **A – E**.

A _____

B _____

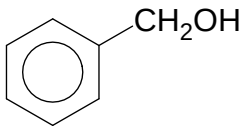
C _____

D _____

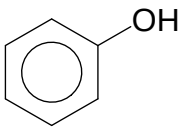
E _____

(5 marks)

(b) Compounds **F** and **G** have different acidic properties and also react differently with acidified potassium permanganate.



F



G

Describe these different behaviours and explain the structural features that give rise to these differences.

(4 marks)

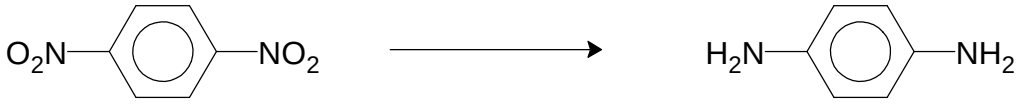
(c) Suggest another method of converting substance **(I)** into substance **(II)** in two steps.

(3 marks)
(Total 12 marks)

DO NOT WRITE ABOVE THIS LINE

9. 1,4–Diaminobenzene is an important industrial material.

(a) 1,4–Diaminobenzene can be manufactured from 1,4–dinitrobenzene.



1,4-dinitrobenzene **1,4–diaminobenzene**

State the reagents and conditions that could be used to carry out this reaction.

(2 marks)

(b) 1,4-Diaminobenzene is an organic base.

(i) Explain how the amino groups in an amine such as 1,4-diaminobenzene allow the molecule to act as a base.

(2 marks)

(ii) 1,4-Diaminobenzene is used to dye hair black but its basic properties cause it to be a skin irritant. In some preparations it is therefore neutralised with **excess** hydrochloric acid. Draw the structure of the salt formed in this reaction.

(1 mark)

(c) Kevlar is a very tough polymer which is used to make bulletproof vests. It is made through the reaction of 1,4-diaminobenzene and benzene–1,4–dicarboxylic acid.

(i) State what type of polymerisation is involved.

(1 mark)

DO NOT WRITE ABOVE THIS LINE

(ii) Write an equation for the reaction and show the structure of the repeat unit.

(2 marks)

(iii) Give the structure and name of an alternative to chemical substance which can be used instead of benzene 1,4–dicarboxylic acid to prepare Kevlar.

(2 marks)
(Total = 10 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2014

SUBJECT:	CHEMISTRY
PAPER NUMBER:	II
DATE:	3rd September 2014
TIME:	9.00 a.m. to 12.00 noon

ANSWER TWO QUESTIONS FROM EACH SECTION AND ANY OTHER QUESTION.

Section A

1. The acid dissociation constant, K_a for ethanoic acid at 298 K is 1.8×10^{-5} mol dm^{-3}.

(a) Calculate the pH and pOH of a 10^{-3} mol dm^{-3} aqueous solution of the acid. (At 298 K, $K_w = 10^{-14}$ mol^2 dm^{-6})

(8 marks)

(b) Calculate the pH of the buffer solution formed when 10.00 cm^3 of 0.10 mol dm^{-3} potassium hydroxide are added to 25.00 cm^3 of 0.40 mol dm^{-3} ethanoic acid.

(6 marks)

(c) Explain why the choice of an indicator for a titration of an acid with a strong base depends on the acid used. Give examples of different types of acids used and the choice of indicator in each case.

(6 marks)
(Total = 20 marks)

2. Consider the following thermochemical data.

Standard enthalpy change of combustion of carbon = –394 kJ mol^{-1}
Standard enthalpy change of formation of water = –286 kJ mol^{-1}

Bond	Average bond enthalpy (kJ/mole)
C – C	347
C – H	413
O – H	464
O = O	495
C = O	805

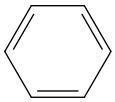
(a) Use the average bond enthalpy values to estimate the enthalpy of combustion of cyclohexane.

(5 marks)

(b) Using the value obtained in (a) and other data given, use Hess' law to estimate the standard enthalpy of formation of cyclohexane.

(5 marks)

(c) The benzene structure is often depicted as that of cyclohexa-1,3,5-triene (below).



Thermochemical data based on calculations show that the enthalpy of hydrogenation of benzene is –208 kJ mol^{-1} whilst that of hypothetical cyclohexa1,3,5-triene should be –359 kJ mol^{-1}. Explain this discrepancy and suggest structural differences between cyclohexa-1,3,5-triene and a benzene molecule. Describe also two differences between chemical properties of benzene and alkenes.

(10 marks)

(Total = 20 marks)

3. (a) Sketch a *Pressure vs Temperature* phase diagram for heptane. On this diagram indicate the triple point and critical point of the substance. Use the diagram to show how an increase in atmospheric pressure results in a change in melting point and boiling point.

(4 marks)

(b) Heptane (saturated vapour pressure at 20°C, 473 Pa) and octane (saturated vapour pressure at 20°C, 140 Pa) mix to give ideal solutions. A solution of the two liquids contains 25.0 g heptane and 50.0 g octane at 20°C; calculate both the partial vapour pressure of each component in the vapour above the mixture and the mole fraction of each component in the vapour phase above the liquid mixture. *(8 marks)*

(c) Mixtures of octane (b.pt. 125°C) and ethanol (b.pt. 78°C) have been studied for the possible use as fuels. Such mixtures did not exhibit ideal solution behaviour. Sketch possible pressure–composition and temperature–composition diagrams for mixtures of these compounds which are known not to be completely separated by distillation and explain the forms of the curve in terms of intermolecular forces.

(8 marks)

(Total = 20 marks)

4. (a) *Transition metals and their ions can play an important part in increasing reaction rates both as homogeneous and heterogeneous catalysts.*

(i) Explain the above statement as fully as possible.

(ii) Iron(II) ions catalyse the reaction between persulfate ($S_2O_8^{2-}$) ions and iodide ions to produce iodine. Explain how and why iron(II) ions catalyse the reaction and write equations for the mechanism of the catalysed reaction as well as for the overall reaction. Explain whether or not the reaction can be catalysed by iron(III) ions.

(12 marks)

(c) *Free radicals may also act as catalysts for certain types of reactions.* Explain, giving the mechanism, how the polymerisation of ethene can be facilitated in the presence of free radicals that readily form from organic peroxides R–O–O–R'.

(8 marks)

(Total = 20 marks)

Section B

5. Compound **A** has the formula C_3H_8O. This can be oxidised to **B** which gives a positive result with Tollen's reagent. Compound **A** reacts with PCl_3 to give **C**. If **C** reacts with ammonia it will give **D**, which can in turn be converted into **A**. If **C** reacts with ethanol in the presence of a base it will give **E**.

Compound **B** reacts with buffered potassium cyanide to give a chiral compound **F** which can be converted to the amino acid **G** which can exist in three forms in aqueous solution depending on the pH.

(a) Identify compounds **A** and **B** and the reagents used to convert **A** to **B**. *(3 marks)*

(b) Identify compounds **C**, **D** and **E** and the reagent that converts **D** to **A**. *(4 marks)*

(c) State the IUPAC name of **F** and draw the chiral molecules of **F**. *(3 marks)*

(d) Suggest a reaction scheme for the conversion of **F** to **G** and give the three possible structural formulae of **G** and the indicative pH values at which they exist. *(10 marks)*

(Total = 20 marks)

6. Nitrobenzene and methylbenzene are two important aromatic compounds.

(a) Describe, giving essential conditions and catalysts, how each compound can be produced from benzene.

(5 marks)

(b) The compounds behave differently in ring-substitution reactions. Explain why there is this difference in behaviour. Your answer should include an example of an electrophilic substitution reaction for each compound along with chemical equations and structures. Suggest a mechanism for an electrophilic substitution for either of the molecules.

(15 marks)

(Total = 20 marks)

7. Addition of sodium carbonate to aqueous Cr^{3+}ions, results in a grey-green precipitate **H** and the release of a colourless gas **I**. Whereas addition of sulfuric(VI) acid and zinc produces a blue solution **J**. Addition of excess sodium hydroxide to **H** will dissolve the precipitate giving a green solution of **K**, however, addition of excess ammonia solution yields a purple solution of **L**. Heating the solution containing **K** with hydrogen peroxide produces a yellow solution of **M**. Acidification of the latter solution gives a solution of **N**.

(a) Identify the species **H** to **N** and write chemical equations for the transformations involved.

(14 marks)

(b) Using the normal convention, write an electrochemical cell that represents the reaction occurring in the reaction that produces **J**. Deduce the polarity of the cell and the reactions occurring in each half cell. *(6 marks)*

(Total = 20 marks)

8. (a) Describe the transformation of the nitrate(V) ion into each of following species: NO, NO_2 and N_2O. *(6 marks)*

(b) Describe the conversion of SO_2 into each of the following species: SO_3^{2-}, SO_4^{2-}. *(4 marks)*

(c) *The sulfur atoms in the $S_2O_3^{2-}$ ion have different oxidation numbers.* Explain this statement. *(2 marks)*

(d) Nitrogen monoxide and sulfur dioxide are both released from power stations using heavy fuel oil as a source of power. A major contributor to the release of nitrogen monoxide in Malta is road traffic.

(i) Explain why both pollutants can cause acid rain.

(ii) Explain why nitrogen monoxide is released from both sources when neither source uses fuel that contains nitrogen.

(iii) Suggest a practical measure that can be used to prevent NO pollution from traffic.

(iv) Suggest a method to reduce sulfur dioxide emissions from a heavy fuel oil fired power station.

(8 marks)

(Total = 20 marks)

Index No.:_____ **AM 06/III.14s**

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD
UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2014

SUBJECT:	CHEMISTRY
PAPER NUMBER:	III – *Practical*
DATE:	29th August 2014
TIME:	3 hours

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

1. In this experiment you are required to determine the concentration of a solution of copper(II) sulphate.

You are supplied with the following chemicals:

(i) approximately 100 cm^3 of 0.500 M sodium thiosulfate labelled T;
(ii) approximately 200 cm^3 of a solution of copper(II) sulfate labelled C_n where n is the candidate laboratory number.

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

CANDIDATE LABORATORY NUMBER, n:.....

*Preparation of the titrating solution of sodium thiosulfate by dilution of solution **T***

(b) In this part of the experiment you are required to dilute solution **T** in order to prepare a sodium thiosulfate solution which you will use to carry out titration with copper sulfate solution $\mathbf{C_n}$**.** The diluted solution will be referred to as **DT**.

Using the burette, transfer 50.0 cm^3 of solution **T** into a 250 cm^3 volumetric flask and dilute to the mark with distilled water. This is solution **DT**.

(c) Calculate the concentration of thiosulfate ion in **DT**.

Determination of the concentration of copper(II) sulfate in solution $\boldsymbol{C_n}$

(d) Pipette 25.0 cm^3 of solution $\mathbf{C_n}$ into a conical flask, add about 10 cm^3 of 10% potassium iodide solution. Titrate with **DT** solution of sodium thiosulfate using starch indicator near the endpoint. Repeat for concordant results. 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 **DT**

(e) *(i)* Given that copper(II) reacts with iodide ions according to the reaction:

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

calculate the molar concentration to three significant figures of copper(II) sulfate in solution.

(f) Assuming 100% purity of the copper(II) sulfate–5–water which was used to prepare solution C_n, deduce the mass of crystals employed for every dm^3 of solution.
(Relative atomic masses: H = 1; O = 16; S = 32; Cu = 63.5)

(50 marks)

Please turn the page.

2. You are provided with two inorganic substances labelled **P** and **Q**. Carry out the tests as described below, record your observations carefully and attempt to identify the compounds.

(a) Dissolve about 0.3 g of substance **P** in approximately 15 cm^3 of water. *Retain this solution for subsequent tests.*

(b) Carry out a flame test on the solution obtained in (a)

Observation	*Inference*

(c) To about 2 cm^3 of the solution from (a), add about 5 cm^3 of dilute sulfuric acid. *Retain the mixture for the next test.*

Observation	*Inference*

(d) Boil carefully the reaction mixture from test (c) and allow to settle for a few minutes. To about 1 cm^3 of the supernatant liquid, add a few drops of aqueous silver nitrate, followed by excess aqueous ammonia.

Observation	*Inference*

(e) Carry out a flame test on solid **Q**.

Observation	*Inference*

(f) Dissolve 0.5 g of substance **Q** in 15 cm^3 of water and acidify about 1 cm^3 of this solution with dilute nitric acid. To this acidified solution add 1 cm^3 of the solution of **P**.

.

Observation	*Inference*

Conclusion

Substance **P** is probably: _____

Substance **Q** is probably: _____

(25 marks)

Please turn the page.

3. You are provided with an organic solid substance **R** having more than one functional group. Perform the following tests on **R** and record your observations and inferences in the spaces provided.

(a) Burn about 0.5 g of **R** on a crucible lid. Do not allow the flame to burn longer than you need to make a good observation.

Observation	*Inference*

(b) Shake a few crystals of **R** with about 3 cm^3 of water. Test with litmus paper. *Keep mixture for tests (c) and (d).*

Observation	*Inference*

(c) To part of the product from test (b), add drops of bromine water until in excess.

Observation	*Inference*

(d) To another part of the product from test (b), add drops of neutral iron(III) chloride solution.

Observation	*Inference*

(e) Add a few crystals of **R** to aqueous sodium carbonate.

Observation	*Inference*

(f) To about 0.3 g **R** add about 3 cm^3 of methanol and one drop of concentrated sulfuric acid (CARE! CORROSIVE) and heat the mixture in a boiling water bath for a few minutes. Tip the products of this reaction into a solution of sodium carbonate and note the odour.

Observation	*Inference*

Conclusion: A possible structure for **R** is:

(25 marks)

BLANK PAGE