Index No.:_____ AM06/I.20s

L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2020 SECOND SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	I
DATE:	14th December 2020
TIME:	4:00 p.m. to 7:05 p.m.

Required Data: Relative atomic masses: I = 126.90
Atomic numbers: Na = 11; Mn = 25; Br = 35
Faraday's Constant = 96500 C mol^{-1}

Answer ALL questions.

1) This question is about atomic structure.

a) An atom consists of a central nucleus, surrounded by electrons. The name and charge of the particles found inside the nucleus are:

Particle name	Charge

(1)

(1)

b) Copper has a relative atomic mass of 63.617. It has two isotopes. One of these isotopes, Cu-63, has an abundance of 69.15%. What is the atomic mass of the second isotope? Show your working.

_____

_____

_____

_____ (2)

c) Complete the following nuclear reactions:

$^{9}_{4}Be + \_\_\_\_\_ \rightarrow ^{12}_{6}C + ^{1}_{0}n$ (1)

$^{14}_{6}C \rightarrow \_\_\_\_\_ + ^{14}_{7}N$ (1)

d) Give the electronic configuration of the following species in s, p, d notation.

Mn^{2+}: _____ (1)

Na^{+}: _____ (1)

Br^{-}: _____ (1)

e) Draw the shape of the following:

s-orbital	
p-orbital	

(1)

(Total: 10 marks)

2) This question is about electronic theory and chemical bonding.

a) Ethene and buta-1,3-diene have carbon atoms which are bonded together. In both cases, the carbon atoms undergo hybridisation.

i) Explain the term hybridisation.

_____

_____ (2)

ii) Name the type of hybridisation which is present in the carbon atoms of ethene and buta-1,3-diene.

_____ (1)

iii) Draw a diagram to show the molecular orbitals in the ethene molecule. Annotate your answer as necessary and name the type of bonds which are formed.

(2)

iv) Explain how the bonding between the carbon atoms in buta-1,3-diene is different to the bonding between the carbon atoms in ethene.

_____

_____

_____ (1)

v) Give the canonical forms for buta-1,3-diene:

(1)

b) Describe and distinguish between a covalent bond and a dative (co-ordinate) bond.

_____

_____

_____ (1)

This question continues on next page.

c) Phosphorus pentachloride exists as PCl_5 molecules in the gaseous phase and as ionic species $[PCl_4]^+$ and $[PCl_6]^-$ in the solid state. Draw and name the geometrical shape of the above three species:

PCl_5

(1)

$[PCl_4]^+$

(1)

$[PCl_6]^-$

(1)

(Total: 11 marks)

3) Answer the following short questions.

a) Describe how nitric(III) acid is prepared in the laboratory. Give a fully balanced equation, including state symbols in your answer.

_____

_____

_____

_____ (3)

b) Explain why water is a liquid at room temperature but hydrogen sulfide is a gas.

_____

_____

_____

_____ (3)

c) Explain how ozone (O_3) forms in the stratosphere.

_____

_____

_____ (2)

(Total: 8 marks)

4) This question is about Group VII in the Periodic Table: the halogens.

a) When moving down Group VII, certain trends in physical and chemical properties can be observed.

i) How does electronegativity change when moving down Group VII? Explain your answer.

_____

_____

_____

_____ (2)

ii) How do the bond dissociation enthalpies of the halogen acids, HX, change when moving down Group VII? Explain your answer.

_____

_____

_____

_____ (2)

This question continues on next page.

b) Iodine is an essential element in the human body. It is needed by the thyroid gland to make hormones, and is given as a medicine to protect the thyroid gland in radiation exposure emergencies.
Iodine has poor solubility in water. In order to facilitate its dissolution, potassium iodide is often used.

i) In the space below, draw the Lewis structure, showing **all** outer shell electrons, for the triiodide ion.

(2)

ii) A standard solution of sodium thiosulfate is being used to determine the concentration of a solution of iodine in potassium iodide. Give a balanced chemical equation for principal reaction occurring in this titration.

_____ (2)

iii) Name a suitable indicator for this reaction which would give a sharp end-point.

_____ (1)

iv) Exactly 22.8 cm^3 of iodine were required to completely react with an aliquot of 25 cm^3 of thiosulfate solution of concentration 0.055 mol dm^{-3}. Calculate the concentration of the iodine solution.

_____

_____

_____

_____ (3)

v) The iodine solution used in this titration was prepared by dissolving a 2.00 g pill containing iodine and other chemicals in 250 cm^3 of potassium iodide solution. Determine the percentage by mass of the pill which is iodine.

_____

_____

_____

_____ (3)

(Total: 15 marks)

5) This question is about redox reactions, with reference to the oxidation and reduction of vanadium.

a) Explain what is meant by the term oxidation number (state).

_____

_____ (2)

b) Calculate the oxidation number (state) of vanadium in VOH^{2+}. All other atoms in this ion have their usual oxidation states. Show your working.

_____

_____

_____ (1)

c) The vanadyl(IV) ion (VO^{2+}) is oxidised to the vanadium(V) ion (V^{5+}) by the manganate(VII) ion, which is in turn reduced to manganese(II), under acidic conditions. Write a fully balanced ionic equation for the reaction between vanadyl sulfate ($VOSO_4$) and potassium permanganate.

_____

_____

_____ (3)

d) Use the data given in Table 1 below to answer the questions which follow.

Table 1: E^o (V)

$V^{2+} + 2e^- \rightleftharpoons V_{(s)}$	$E^o = -1.13$
$Fe^{2+} + 2e^- \rightleftharpoons Fe_{(s)}$	$E^o = -0.440$
$V^{3+} + e^- \rightleftharpoons V^{2+}$	$E^o = -0.260$
$Cu^{2+} + 2e^- \rightleftharpoons Cu_{(s)}$	$E^o = +0.337$

i) What does the term E^o stand for?

_____ (1)

ii) Using the data given in the Table 1 above only, state whether you would expect vanadium to corrode in air or not. Give a reason for your answer.

_____

_____ (2)

This question continues on next page.

iii) Using the data given in the Table 1 above only, state whether you would expect V^{2+} or V^{3+} to be the more stable of these two ions under standard conditions. Give a reason for your answer.

_____

_____ (2)

iv) Calculate the electrode redox potential and Gibbs Free Energy change for the $V_{(s)}|V^{2+}_{(aq)}||Cu^{2+}_{(aq)}|Cu_{(s)}$ cell. Include equations and balanced ionic reactions in your answer where appropriate.

_____

_____

_____

_____

_____

_____

_____

_____ (4)

(Total: 15 marks)

6) The elements carbon and lead are elements of Group IV of the Periodic Table.

a) This part of the question is about lead.

i) When a solution of sodium chlorate(I) is added to lead nitrate solution a brown precipitate X is formed. Identify X and give a fully balanced equation including state symbols for this reaction.

_____

_____

_____ (2)

ii) The brown precipitate formed in part a (i) above dissolves in concentrated hydrochloric acid at room temperature to form a yellow liquid Y. Identify Y. Give **TWO** balanced equations in your answer.

_____

_____

_____

_____ (3)

iii) Give balanced chemical equations including state symbols to show the action of water on:

lead(II) chloride

_____ (1)

lead(IV) chloride

_____ (1)

b) This part of the question is about carbon monoxide.

i) Describe **ONE** method for the preparation of CO in the laboratory. Include a balanced equation in your answer.

_____

_____

_____ (2)

ii) Draw the molecular structure of CO.

(1)

iii) Explain why CO is a good ligand.

_____

_____

_____ (2)

iv) Give the structure of the complex $[Cr(CO)_6]^{3+}$.

(1)

This question continues on next page.

v) Give a balanced chemical equation including state symbols where CO is acting as a reducing agent in the extraction of a metal.

_____ (1)

vi) In industry, methanoic acid is produced by the reaction of carbon monoxide with molten sodium hydroxide. Write balanced equation/s and explain whether it can be described as a redox reaction.

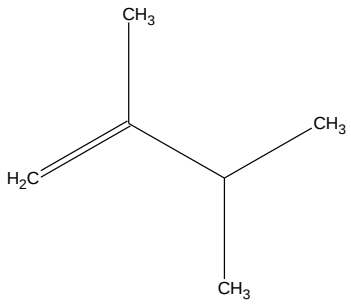
_____

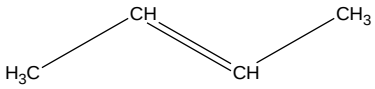
_____

_____ (2)

(Total: 16 marks)

7) This question is about the organic molecules below:

A: 

B: 

a) Give the systematic name of organic compounds A and B.

A:_____

B:_____ (1)

b) The label of a container containing one of the above two organic molecules has deteriorated. A student performs experiments to identify the compound in the container.

i) Name a chemical method which may be used to determine whether A or B is present in the container.

_____ (1)

ii) Give the reagents needed and the expected product/s when organic compound B undergoes the method proposed in part b (i) above.

Reagents: _____ (1)

Product/s:_____ (1)

iii) Show the structure of any intermediates that are produced in the chemical reaction in part b (ii) above.

(1)

c) Molecules A and B can react with hydrogen bromide.

i) Name **OR** draw the structure of the product formed when hydrogen bromide reacts with molecule A.

_____ (1)

ii) The reaction of hydrogen bromide with molecule A can, in theory, produce a second product. Identify this product and explain in terms of carbocation stability why it is not the major product.

_____

_____

_____

_____ (3)

This question continues on next page.

d) Starting from molecule B, show how you can produce propanoic acid. More than one step may be required. You may use any inorganic reagents.

(5)

(Total: 14 marks)

8) This question is about alcohols and phenol.

a) Phenol has a pK_a of 9.9 at 25 °C, while cylohexanol has a pK_a of 16.0 at the same temperature. Explain in terms of the structure of both compounds the reason why one is more acidic than the other.

_____

_____

_____ (2)

b) Give a chemical equation for the reaction of phenol with sodium hydroxide.

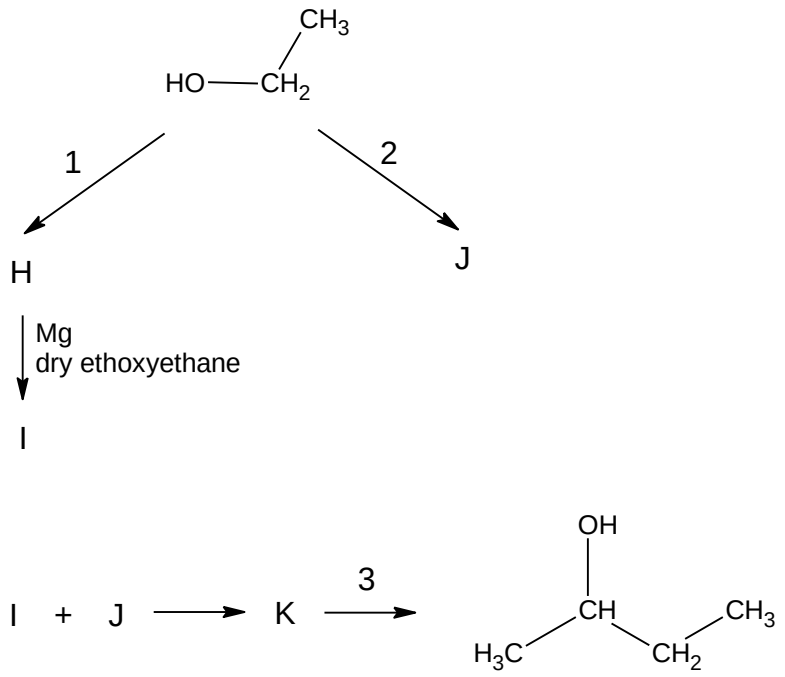
_____ (1)

c) Does phenol react with sodium carbonate? Explain your answer.

_____

_____ (2)

d) Consider the following reaction scheme:



i) Give the structural formulae for organic compounds **H**, **I**, **J**, **K**.

H: (1)

I: (1)

J: (1)

K: (1)

This question continues on next page.

ii) Name the reagents and conditions in reactions 1, 2 and 3.

1: _____ 2: _____

3: _____ (2)

(Total: 11 marks)

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MATRICULATION AND SECONDARY EDUCATION CERTIFICATE
EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2020 SECOND SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	II
DATE:	15th December 2020
TIME:	4:00 p.m. to 7:05 p.m.

A Periodic Table is provided.

Answer TWO questions from each section and ANY other question.

SECTION A

1) Nitrogen, N_2, is an inert gas which can be made to react to produce both a very basic compound such as ammonia, and a very acidic compound such as nitric(V) acid.

   a) Explain the lack of reactivity of nitrogen gas. (1)
   b) Give balanced chemical equations and the conditions required to form ammonia from nitrogen gas. (2)
   c) Explain how nitric(V) acid can be changed to ammonia, giving a balanced chemical equation. (2)
   d) A 5 dm^3 container under vacuum is filled with 250 cm^3 of a solution which is made of 5 moles of nitric(V) acid and 15 moles of water. Nitric(V) acid and water have vapour pressures of 6.40 kPa and 2.34 kPa respectively. Assuming ideal behaviour, determine the theoretical total vapour pressure present in the container. (4)
   e) Explain why the theoretical value for the total vapour pressure of the mixture as calculated in part d) would be different from the actual measured value observed in reality. (2)
   f) Sketch the Maxwell-Boltzmann distribution for a fixed amount of gas at two different temperatures. Remember to label which sketch is at the higher temperature and which is at the lower temperature. Use your two sketches to explain the physical basis of the Gay-Lussac Law. (5)
   g) State **FOUR** basic assumptions of the ideal gas model. Relate these assumptions to the Van der Waals equation. (4)

(Total: 20 marks)

Please turn the page.

2) This question is about Ionic Equilibria.

a) The K_a of benzoic acid is 6.46 x10^{-5}. 2.00 g of benzoic acid were added to 1 dm^3 of a 0.0150 mol/dm^3 solution of sodium benzoate. Calculate the pH of the resulting solution. Assume that the benzoic acid dissolves completely and that it dissociates completely in solution. (4)

b) Explain the function of buffer solutions. Use Le Chatelier's Principle to explain the means through which these solutions achieve their function. (5)

c) An experiment is being performed to determine the K_{sp} of calcium chromate(VI) dihydrate. Exactly 1.125 g of this salt dissolve in 50 cm^3 of distilled water to form a saturated solution. Use this information to determine the K_{sp} of calcium chromate(VI). State any assumptions taken. (4)

d) The solubility of calcium chromate(VI) is affected by its interaction with the ions naturally present in distilled water. Discuss this statement. (2)

e) Rhodamine B is an organic molecule with a strong, bright pink colour when in solution. It contains a single carboxylic acid group which makes the molecule a weak acid when in solution. Explain how to carry out and interpret the results of a conductimetric titration to determine the concentration of rhodamine B in a solution of unknown concentration. In your answer include an explanation of the chemical principles involved in this method. (5)

(Total: 20 marks)

3) Calcium oxide, also known as quicklime, is an important chemical in the lime cycle. It is an intermediate chemical in the production of calcium hydroxide from calcium carbonate. The dissolution of calcium oxide in water is highly exothermic, so much so that it was used as a primitive chemical weapon by the Romans in 80 BC.

a) Construct the Born-Haber cycle which can be used to find the enthalpy of formation of calcium oxide. Name **all** the steps in the cycle, but do **not** include numerical values. (6)

b) Distinguish between the enthalpy of solution (or dissolution) and the enthalpy of hydration using calcium oxide as an example. Construct a labelled Hess' cycle as part of your answer. (4)

c) Use the data given in the table below to calculate the standard Gibbs' energy for the change under standard conditions of temperature and pressure:

$$Ca(OH)_{2(s)} \rightarrow Ca^{2+}_{(aq)} + 2\ OH^{-}_{(aq)}$$

	$Ca(OH)_{2(s)}$	**$Ca^{2+}_{(aq)}$**	**$OH^{-}_{(aq)}$**
$\Delta H°_{formation}$ (kJ/mol)	-986	-543	-230
$\Delta S°$ (J/mol/K)	83.4	-53.1	-10.8

(5)

d) An aqueous solution of calcium hydroxide reacts with carbon dioxide to form the carbonate. Is the entropy change for this reaction positive or negative? Give reasons for your answer. (2)

e) Explain the difference between kinetic and thermodynamic stability and how they are interlinked. (3)

(Total: 20 marks)

4) This question is about inorganic chemistry.

a) Explain how the production of hydrogen gas is achieved in the laboratory from zinc. Include a brief description of how the hydrogen gas is collected and give a fully balanced equation including state symbols in your answer. (3)

b) Describe the bonding in lithium tetrahydridoaluminate and describe how this compound may be prepared in the laboratory. In your answer, give a fully balanced equation including state symbols. (4)

c) A student carried out a number of tests on two unknown inorganic substances labelled as **M** and **O** in order to deduce their chemical composition. The two substances are soluble in water. The tests carried out, together with the observations done by the student are given below. Each test was carried out for each substance individually.

	Test		**Observation**
1	To about 1 cm^3 of the unknown solution, aqueous sodium hydroxide was added drop-wise, until in excess.	M:	No visible change.
		O:	White precipitate forms which is soluble in excess.
2	To about 1 cm^3 of the unknown solution, aqueous ammonia was added drop-wise, until in excess.	M:	No visible change.
		O:	White precipitate forms which is insoluble in excess.
3	To about 1 cm^3 of O, 1 cm^3 of aqueous sodium hydrogen carbonate was added.	O:	A white precipitate formed and a colourless gas that turned lime water milky was evolved.
4	A flame test was carried out on substance M.	M:	A yellow orange flame was observed.
5	To 1 cm^3 of the unknown solution, a solution of iron(II) sulfate was added. This was followed by the drop-wise addition of concentrated sulfuric acid, forming two layers.	All:	A brown ring was observed between the two layers.

i) Give a detailed interpretation for **each** test and include full balanced equations with state symbols for tests 1, 2, 3 and 5. (12)

ii) Suggest a chemical formula for **M** and **O**. (1)

(Total: 20 marks)

Please turn the page.

SECTION B

5) This question is about copper and organic compounds.

a) Give a fully balanced equation, including state symbols, showing the reaction of copper with concentrated sulphuric(VI) acid. (1)

b) Describe how copper(II) nitrate can be prepared in the laboratory. In your answer include a fully balanced equation including state symbols for this preparation. (3)

c) A complex of copper is formed when ethanol and glycine are added to a solution of very hot copper(II) ethanoate. This complex may exist as one of two isomers. Name these isomers and draw the structure of **ONE** of them. (2)

d) An organic substance **G**, having a simple formula C_3H_6O, produces a red precipitate (**I**), when tested with Fehling's reagent.

i) Identify organic substance **G** and the red precipitate **I**. Write an equation for this reaction. (3)

ii) Give an equation for the reaction of the red precipitate **I** with HCl. (1)

iii) When substance **G** reacts with HCN, substance **H** is obtained. Identify substance **H** and discuss if any isomers will be obtained from this reaction. (3)

iv) Give a mechanism for the reaction of substance **G** with HCN. (3)

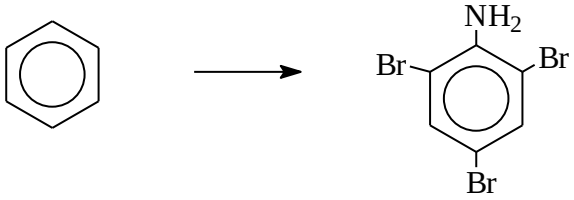
v) Show how substance H can be converted to the corresponding amino-acid. More than one step may be required. Your answers should include reagents and conditions used where appropriate. (4)

(Total: 20 marks)

6) This question is about organic chemistry.

a) Give the mechanism for the reaction of Cl_2 with but-2-ene. (3)

b) Explain how you would carry out the following conversion. More than one step may be required. Your answers should include reagents and conditions used where appropriate.



(4)

c) Give a reaction scheme showing how you may obtain 1-phenylethanone. The only organic reagents available to you are phenol and ethanol. You may use any inorganic reagent. More than one step may be required. Your answers should include reagents and conditions used where appropriate. (5)

d) Describe what is meant by a zwitterion. Explain the behaviour of amino acids in acidic solutions, alkaline solutions and at the isoelectric point, when an electric field is applied. (5)

e) One of the separation techniques used in the isolation of phenylamine is steam distillation. Describe how this processes works by explaining the physical principles on which this technique is based. (3)

(Total: 20 marks)

7) This question is about polymers and their monomers.
   a) The polyamide Nylon-6,6 is produced in industry from the reaction of hexandioic acid and hexane-1,6-diamine.
      i) Give a reaction scheme showing how hexandioic acid and hexane-1,6-diamine may be produced from butane-1,4-diol. More than one step may be required. Your answer should include the conditions and the reagents which are used in **all** the steps. (5)
      ii) Show, by giving a chemical equation, how Nylon-6,6 may be prepared from its monomers. (1)
   b) Another important polymer is the polyester poly(ethylene terephalate). This polyester is produced from the reaction of benzene-1,4-dicarboxylic acid and ethane-1,2-diol.
      i) Give a chemical reaction showing the formation of poly(ethylene terephalate) from its monomers. (1)
      ii) Give a reaction scheme showing how benzene-1,4-dicarboxylic acid may be prepared from benzene. More than one step may be required. Your answer should include the conditions and the reagents which are used in **all** the steps. (5)
      iii) The melting point of benzene-1,4-dicarboxylic acid is above 300 °C while benzene-1,2-dicarboxylic acid has a melting point of 207 °C. Explain why there is such a large difference in melting points in these two isomers. (3)
      iv) When heating benzene-1,2-dicarboxylic acid, water is given off. Explain this observation and write a chemical equation for this reaction to illustrate the process. (2)
   c) Explain why polyesters are environmentally friendly polymers when compared to poly(alkenes)s. (3)

(Total: 20 marks)

8) 2-Methylpropan-2-ol is being synthesised from 2-methyl-2-chloropropane.
   a) Besides 2-methyl-2-chloropropane, name the other reactant/s required in order to perform this synthesis reaction in one-step. Give the conditions required. (1)
   b) It was noted that the rate of reaction was very slow. Explain how **ONE** of the starting reactants could be changed to increase the rate of reaction while giving the same product. (2)
   c) Once the synthesis reaction is performed, the reaction does not go to completion. The resulting mixture contains the product, biproducts, and unreacted starting compounds. Most of the unreacted halogenoalkane can be removed through solvent extraction.
      i) Explain the chemical principles which form the basis of the solvent extraction process. (2)
      ii) Calculate the percentage of unreacted halogenoalkane which can be extracted from the reaction mixture if the reaction mixture is washed once with a volume of solvent equal to the reaction mixture. The partition coefficient for the halogenoalkane between the solvent and the mixture is exactly 2.00. (4)
   d) Fractional distillation can be used to purify the desired alcohol product from the biproduct and any other unreacted reactants. Explain in detail how this purification method works. In your answer include a labelled diagram of the set-up and a phase diagram. (6)
   e) The purified product is finally analysed through mass spectrometry.
      i) Draw a well-labelled diagram of the mass spectrum. (3)
      ii) Give the chemical structure associated with any **TWO** peaks in the mass spectrum which you would expect to observe for the product, but **not** for the original halogenoalkane. (2)

(Total: 20 marks)