Index Number:_____ IM06.19m

L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

INTERMEDIATE MATRICULATION LEVEL
2019 FIRST SESSION

SUBJECT:	**Chemistry**
DATE:	22nd May 2019
TIME:	9:00 a.m. to 12:05 p.m.

Useful information

Molar gas constant R = 8.31 $Jmol^{-1}K^{-1}$
Relative atomic masses: H=1, C =12, O = 16, K = 39, Ca = 40, Fe = 56, I =127
A Periodic Table is included.

SECTION A

Answer ALL questions in this section.

1. (a) A hydrocarbon Y contains 85.7% carbon and 14.3% hydrogen by mass.
(i) Calculate the empirical formula of the hydrocarbon Y.

_____

_____

_____ (1)

(ii) The molar mass of the hydrocarbon Y is 56 g. Deduce the molecular formula of the hydrocarbon Y.

_____

_____ (1)

(b) The analyst who wanted to identify the hydrocarbon Y, was certain that the compound was a saturated hydrocarbon. Suggest a structure for this saturated hydrocarbon Y. Name the hydrocarbon Y.

Structure:

Name: _____ (1)

(Total: 3 marks)

2. The standard heat of formation of water in the gaseous state is -242 $kJmol^{-1}$.
   (a) Write an equation which represents the standard heat of formation of water in the gaseous state.

_____ (1)

   (b) Circle the correct value of the standard heat of combustion of gaseous hydrogen.

   -121 $kJmol^{-1}$ -80.6 $kJmol^{-1}$ -242 $kJmol^{-1}$ -484 $kJmol^{-1}$ (1)

   (c) Why is hydrogen considered to be a clean fuel?

_____ (1)

(Total: 3 marks)

3. There are four isomeric alkenes of molecular formula C_4H_8. In the space below, draw the structure of each isomer. Write the name of each isomer under each structure.

(Total: 4 marks)

4. Carbon-14 in the atmosphere undergoes beta-decay and produces 60 atoms of nitrogen-14 every hour for each gramme of carbon. The disintegration rate is 60 counts $hour^{-1}g^{-1}$.
   (a) Write a balanced nuclear equation which shows the decay reaction of carbon-14.

_____ (2)

   (b) A small piece of sea shell which was embedded in a rock was found to have a count of 3.75 counts $hour^{-1}g^{-1}$. The half-life of carbon-14 is 5730 years. Estimate the age of the seashell.

_____

_____

_____ (2)

(Total: 4 marks)

5. (a) Draw dot-cross diagrams for the following molecules:

Aluminium chloride ($AlCl_3$)

Ammonia (NH_3)

Ammonium ion (NH_4^+)

Hydronium ion (H_3O^+)

(2)

(b) In the table below, write the shape of each of the species.

Species	Shape
Aluminium chloride ($AlCl_3$)	
Ammonia (NH_3)	
Ammonium ion (NH_4^+)	
Hydronium ion (H_3O^+)	

(2)

(Total: 4 marks)

Please turn the page.

6. Polyvinyl chloride (PVC) is an addition polymer made from the monomer monochloroethene.
   (a) What is an addition polymer?

_____

_____

_____ (1½)

   (b) Draw the structural formula of monochloroethene.

(1)

   (c) Draw the repeating unit of the polymer PVC.

(1½)
(Total: 4 marks)

7. The reaction mechanism of the addition of hydrogen bromide to ethene is described as a multistep reaction mechanism.
   (a) Draw a diagram to show the mechanism and the steps of this reaction. *(In your diagram, use arrows to show the movement of electrons.)*

(2)

   (b) Explain the term rate-determining step.

_____

_____ (1)

   (c) In your diagram in part 7(a), label clearly the rate determining step. (1)
(Total: 4 marks)

8. The hydrogenation of ethene is an exothermic reaction. This reaction is catalysed by Raney Nickel.

(a) Explain in terms of activation energy, what Raney Nickel does as a catalyst in this reaction.

(1)

(b) Draw an energy profile diagram for the catalysed and the non-catalysed hydrogenation reaction. In your diagram label the activation energy of the catalysed reaction ($E_{a/cat}$), the activation energy of the non-catalysed reaction ($E_{a/non\text{-}cat}$) and the heat of the reaction (ΔH).

(3)

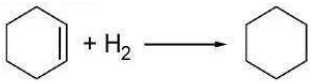
(Total: 4 marks)

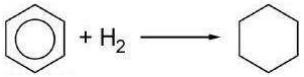
Please turn the page.

SECTION B

Answer ALL questions in this section.

9. (a) The following two equations represent addition reactions in organic chemistry. They show the enthalpies of reaction of the hydrogenation of cyclohexene and the hydrogenation of benzene. Both compounds, when hydrogenated, give the same product.

Reaction 1  $\Delta H = -120\ kJmol^{-1}$

Reaction 2  $\Delta H = -208\ kJmol^{-1}$

(i) Describe the bonding between the atoms in the benzene molecule.

_____

_____

_____ (1)

(ii) Explain why the enthalpy of hydrogenation in Reaction 2 is less exothermic than three times the enthalpy of hydrogenation in Reaction 1.

_____

_____

_____ (1)

(b) (i) Benzene undergoes substitution reactions rather than addition reactions. Explain this statement.

_____

_____

_____ (1)

(ii) Give an equation for the mononitration of benzene.

_____

_____ (1)

(iii) Name the reagents which are used in the above reaction.

_____ (1)

(iv) State the conditions which are used in this reaction.

_____

_____ (1)

(Total: 6 marks)

10. (a) A mixture of gases composed of 44 g of propane and 224 g of oxygen is ignited in a vessel of volume 10 dm^3. The temperature rises from 25 °C to 327 °C.

(i) Find the number of moles of propane and the number of moles of oxygen present in the mixture.

(2)

(ii) Write an equation for the combustion of propane.

(½)

(iii) Find the total number of moles of gas left immediately after the reaction at 600 K.

(1)

(iv) Calculate the pressure inside the vessel immediately after the reaction.

(1)

(b) The carbon dioxide which is produced in the combustion reaction is bubbled through lime water. The following equation represents this reaction.

$$Ca(OH)_2\ (aq) + CO_2\ (g) \longrightarrow CaCO_3\ (s) + H_2O\ (l)$$

Calculate the mass of calcium carbonate which is precipitated.

(1½)

(Total: 6 marks)

11. (a) Sodium, aluminium and sulfur are elements in Period 3. Describe the reactivity (if any) of the oxides of these elements with water. *(Include chemical equations where relevant.)*

(3)

This question continues on the next page.

(b) The following table gives the melting point of three Period 3 oxides.

Oxide	Melting point (^{O}C)
Na_2O	1132
SiO_2	1700
SO_2	-72

Explain the differences in the melting points of sodium oxide, silicon dioxide and sulfur dioxide.

_____

_____

_____

_____

_____

_____ (3)

(Total: 6 marks)

12. (a) Potassium iodate reacts with potassium iodide in acid solution to release iodine. The redox ionic equation for this reaction is:

$$IO_3^-\,(aq) + 5I^-\,(aq) + 6H^+\,(aq) \longrightarrow 3I_2\,(aq) + 3H_2O\,(l)$$

(i) Give the oxidation number of iodine in:

I^-: _____ (½)

IO_3^-: _____ (½)

(ii) Write a balanced ionic equation to show the oxidation half-reaction in the above reaction.

_____ (1)

(iii) Write a balanced ionic equation to show the reduction half reaction in the above reaction.

_____ (1)

(b) In an experiment, 0.4 g of potassium iodate (KIO_3) is dissolved in water and made up to 250 cm^3 in a volumetric flask. Three 25 cm^3 samples of the solution were separately added to an excess of potassium iodide in acid solution in conical flasks. The iodine which formed in each flask reacted with sodium thiosulfate from a burette in a titration.

$$I_2 + 2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2I^-$$

The following table gives the three titre values of the titrations.

Burette reading	Titration 1	Titration 2	Titration 3
Final (cm^3)	22.45	32.20	34.30
Initial (cm^3)	0.00	10.00	12.00

(i) Calculate the number of moles of potassium iodate in the 0.4 g sample.

(½)

(ii) Calculate the number of moles of potassium iodate in the 25 cm^3 sample placed in each conical flask.

(½)

(iii) Calculate the number of moles of iodine which were formed in each conical flask.

(½)

(iv) Calculate the number of moles of thiosulfate which reacted with iodine in each conical flask.

(½)

(v) What is the concentration of the sodium thiosulfate solution?

(1)

(Total: 6 marks)

13. Ethene is used as a starting material in the industrial production of ethanol. The ethene is reacted with steam at around 6 x 10^6 Nm^{-2} and at a temperature of 300 °C. The catalyst in this reaction is phosphoric acid. Under these conditions, 5% of the reactants are converted into ethanol.

$CH_2{=}CH_2$ (g) + H_2O (g) $\rightleftharpoons$ CH_3CH_2OH (g) $\quad \Delta H^{\ominus} = -46$ kJmol^{-1}

(a) (i) Explain, in terms of Le Chatelier's principle, why a high pressure favours the production of ethanol.

(2)

(ii) Give **ONE** disadvantage of using a high pressure in an industrial process.

(½)

This question continues on the next page.

(b) (i) Explain, in terms of Le Chatelier's principle, why a low temperature favours the formation of ethanol.

(2)

(ii) Give **ONE** disadvantage of using a low temperature in an industrial process.

(½)

(c) (i) How does phosphoric acid affect the position of equilibrium in the production of ethanol?

(½)

(ii) What happens if phosphoric acid is **not** used in the reaction?

(½)

(Total: 6 marks)

SECTION C

Answer any TWO questions from this section. Write your answers on the lined pages of this booklet.

14. (a) There are acids, bases and alkalis.
(i) Give the Arrhenius definition of the terms acid and base, i.e. in terms of H^+ and OH^-. (2)
(ii) Distinguish between a base and an alkali. (1)
(iii) There are strong and weak acids and bases. Distinguish between the terms strong and weak in this context. (1)
(iv) Give an example of each of the following: a strong acid, a weak acid, a strong base, a weak base. (2)
(v) Explain the term amphoteric. (1)
(vi) Water is an amphoteric compound. Give **TWO** reactions of water to show this behaviour. (2)
(vii) Give the Lowry-Bronsted definition of the terms acid and base. (2)
(viii) Nitric acid reacts with methanol as follows:

$$HNO_3 + CH_3OH \rightleftharpoons NO_3^- + CH_3OH_2^+$$

Indicate the acid, the base, the conjugate acid and the conjugate base for this acid-base reaction. (2)

(b) A volume of 20.0 cm^3 of 0.1 $moldm^{-3}$ hydrochloric acid is poured into a beaker, to which 18.0 cm^3 of 0.1 $moldm^{-3}$ sodium hydroxide solution are added.
(i) Find the pH of the original hydrochloric acid solution. (1)
(ii) Write the chemical equation that represents the reaction between hydrochloric acid and sodium hydroxide solution, including state symbols. (1)
(iii) What is the H^+ concentration of resulting solution after the sodium hydroxide solution is added to the hydrochloric acid solution. (4)
(iv) Find the pH of the final solution. (1)

(Total: 20 marks)

15. (a) Potassium manganate(VII), or potassium permanganate, $KMnO_4$, in acidified solution, is titrated against a solution containing iron(II) ions, and turns to manganese(II) ions.

(i) Write the half equation that shows the change from acidified manganate(VII) to manganese(II) ions. (2)

(ii) Write the half equation that shows the change that iron(II) undergoes when it is titrated with acidified manganate(VII). (1)

(iii) Join the **TWO** half equations in parts (i) and (ii), and write the full redox reaction between acidified manganate(VII) and iron(II). (1)

(iv) Why is there no need for an indicator in the titration between acidified manganate(VII) and iron(II)? (1)

(b) The following procedure was carried out:

- An iron tablet was weighed and transferred to a beaker; 100 cm^3 of deionised water were added, and heated to dissolve the tablet.
- The solution was allowed to cool and transferred to a 250 cm^3 volumetric flask, and made up to the mark with deionised water.
- 1000 cm^3 of 0.01 $moldm^{-3}$ potassium manganate(VII) solution were prepared; it was acidified by 2 $moldm^{-3}$ sulphuric acid.
- 10 cm^3 of the acidified 0.01 $moldm^{-3}$ potassium manganate(VII) solution were pipetted into a conical flask.
- The unknown iron(II) solution was run into the flask from a burette, recording the end point.
- The titration was repeated until concordant results are obtained. The results were:

Titre	Initial (cm^3)	Final (cm^3)	Titre value (cm^3)
1	0.00	22.08	
2	0.05	27.95	
3	0.00	27.90	

(i) Why was the solution allowed to cool before it was transferred to the 250 cm^3 volumetric flask? (1)

(ii) What is meant by concordant results? Indicate the concordant titre values. (1)

(iii) Find the mass of iron per tablet in mg. (6)

(c) A dry sample of a mixture of $CaCO_3$ and $CaCl_2$ has a mass of 1.45 g. It was dissolved in 25.00 cm^3 of 0.98 $moldm^{-3}$ HCl solution. A volume of 21.48 cm^3 of 0.09 $moldm^{-3}$ NaOH solution was used to titrate the excess HCl.
What was the percentage of $CaCl_2$ in the original mixture? (7)

(Total: 20 marks)

16. (a) Chlorine (and bromine) react with and oxidise thiosulfate. Iodine oxidises thiosulfate too, but it does so differently.

(i) Give the reaction of chlorine with thiosulfate. (2)

(ii) Give the reaction of iodine with thiosulfate. (2)

(iii) Considering the reaction of chlorine with thiosulfate, by assigning oxidation numbers to every element, indicate what is oxidised and what is reduced. (5)

(iv) Considering the reaction of iodine with thiosulfate, by assigning oxidation numbers to every element, indicate the oxidising agent and the reducing agent. (5)

(b) We speak of the relative oxidising power of the halogens. Explain, by considering the **THREE** halogens chlorine, bromine and iodine. Include chemical equations wherever necessary. (6)

(Total: 20 marks)

Please turn the page.

17. Explain each of the following statements, illustrating your answer with suitable chemical reactions wherever possible.
    (a) Esters are produced through one of the typical reactions of alcohols, in the presence of a catalyst. (4)
    (b) Alcohols react with PCl_5 and with sodium. (4)
    (c) Primary, secondary and tertiary alcohols can be distinguished through their oxidation reactions. (6)
    (d) Alcohols can either be dehydrated to alkenes or to ethers. (6)

(Total: 20 marks)

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PERIODIC TABLE

I	II											III	IV	V	VI	VII	VIII
																	4 He 2
7 Li 3	9 Be 4											11 B 5	12 C 6	14 N 7	16 O 8	19 F 9	20 Ne 10
23 Na 11	24 Mg 12											27 Al 13	28 Si 14	31 P 15	32 S 16	35.5 Cl 17	40 Ar 18
39 K 19	40 Ca 20	45 Sc 21	48 Ti 22	51 V 23	52 Cr 24	55 Mn 25	56 Fe 26	59 Co 27	59 Ni 28	63.5 Cu 29	65 Zn 30	70 Ga 31	73 Ge 32	75 As 33	79 Se 34	80 Br 35	84 Kr 36
85 Rb 37	88 Sr 38	89 Y 39	91 Zr 40	93 Nb 41	96 Mo 42	99 Tc 43	101 Ru 44	103 Rh 45	106 Pd 46	108 Ag 47	112 Cd 48	115 In 49	119 Sn 50	122 Sb 51	128 Te 52	127 I 53	131 Xe 54
133 Cs 55	137 Ba 56	139 La 57	178.5 Hf 72	181 Ta 73	184 W 74	186 Re 75	190 Os 76	192 Ir 77	195 Pt 78	197 Au 79	201 Hg 80	204 Tl 81	207 Pb 82	209 Bi 83	209 Po 84	210 At 85	222 Rn 86
223 Fr 87	226 Ra 88	227 Ac 89															

Key

Relative atomic mass — A
X
Z — *Atomic Number*

140 Ce 58	141 Pr 59	144 Nd 60	147 Pm 61	150 Sm 62	152 Eu 63	157 Gd 64	159 Tb 65	162 Dy 66	165 Ho 67	167 Er 68	169 Tm 69	173 Yb 70	175 Lu 71
232 Th 90	231 Pa 91	238 U 92	237 Np 93	244 Pu 94	243 Am 95	247 Cm 96	247 Bk 97	251 Cf 98	252 Es 99	257 Fm 100	258 Md 101	259 No 102	260 Lr 103