Index Number:_____ IM06.24m

L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

INTERMEDIATE MATRICULATION LEVEL
2024 FIRST SESSION

SUBJECT:	**Chemistry**
DATE:	22nd May 2024
TIME:	9:00 a.m. to 12:05 p.m.

Useful information
Ideal gas constant = 8.314 $JK^{-1}mol^{-1}$
Relative atomic masses: H = 1, C = 12, O = 16, Fe = 56
A Periodic Table is included.

SECTION A
Answer ALL questions in this section.

1. (a) Mark the following statements on isotopes as True or False.

	True	False
Isotopes of the same element have the same atomic number		
Isotopes of the same element have the same number of protons		
Isotopes of the same element have a different number of neutrons		

(1½)

(b) Calculate the relative atomic mass of copper assuming it to contain 70% of copper-63 and 30% of copper-65.

_____

_____

_____ (1½)

(Total: 3 marks)

2. An organic liquid Y of molar mass 44 $gmol^{-1}$ contains 54.5% carbon, 36.4% oxygen and the rest is hydrogen.
(a) Find the empirical formula of Y.

_____

_____

_____

_____

_____ (2)

This question continues on the next page.

(b) Deduce the molecular formula of Y.

_____

_____

_____ (1)

(Total: 3 marks)

3. (a) From the following list, underline the species which has a dative bond. (1)

MgO CH_4 NH_4^+ BF_3

(b) Write the name of the complex $[Fe(H_2O)_6]^{3+}$.

_____ (1)

(c) Describe the metal-ligand bonding in the complex $[Fe(H_2O)_6]^{3+}$.

_____

_____

_____

_____ (2)

(Total: 4 marks)

4. The following graph shows how the concentration of product B changes with time in the hypothetical reaction A (g) → B (g).

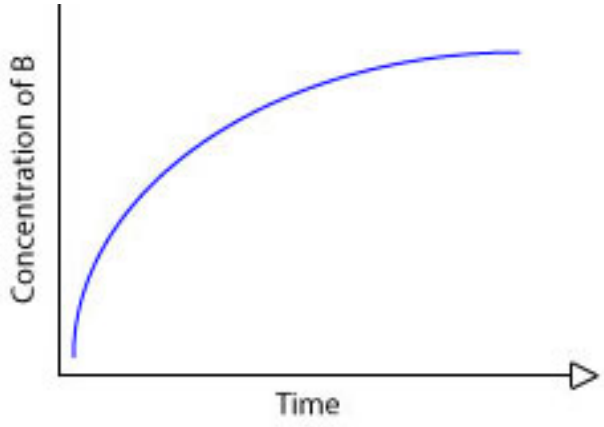


Figure 1

(a) Indicate with an arrow the region where the rate of formation of product B is fastest. (1)

(b) Explain why the curve in Figure 1 levels off (at the top right corner).

_____

_____

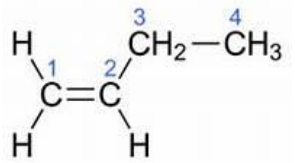
_____ (1)

(c) In the space below draw a graph, using appropriately labelled axes, that shows the rate of change of the concentration of A with time.

(2)

(Total: 4 marks)

5. The structural formula of but-1-ene is given below. The numbers 1, 2, 3 and 4 serve for labelling purposes only. Bonds between carbon atoms may be sigma or pi bonds.



(Source: https://en.wikipedia.org/wiki/but-1-ene)

(a) Draw a circle around the pi (π) bond in the above diagram of but-1-ene. (1)

(b) In the following Table, write the spatial distribution of bonds around C1 and C4 in terms of geometrical arrangement and bond angles in the above diagram. (3)

C atom	Geometrical Arrangement	Bond angle in degrees
C1		
C4		

(Total: 4 marks)

Please turn the page.

6. (a) A student wanted to investigate the purity of a white powder A. This powder melted over a two-degree range of temperature.

(i) Define the term melting point of a substance.

_____

_____

_____ (1)

(ii) What do you conclude about the purity of the white powder A? Give reasons for your answer.

_____

_____ (1)

(b) In another experiment, the same student prepared 1.6 g of dry copper(II) sulfate. This may be prepared by the reaction of copper oxide with dilute sulfuric(VI) acid.

(i) Write a balanced equation, showing states, for the reaction between copper(II) oxide and sulfuric(VI) acid.

_____ (1)

(ii) Calculate the percentage yield if the theoretical yield of this reaction is 2.0 g.

_____

_____ (1)

(Total: 4 marks)

7. Explain the following statements about first ionisation energies. In your answer refer to the electron configuration of the elements.

(a) Sodium has a lower ionisation energy than lithium.

_____

_____

_____

_____ (2)

(b) Oxygen has a lower ionisation energy than nitrogen.

_____

_____

_____

_____

_____ (2)

(Total: 4 marks)

8. Some d block elements are not transition metals.
   (a) What is a transition metal?

   _____

   _____

   _____ (1)

   (b) Give **ONE** example of a first-row d block element which is **not** a transition metal.

   _____

   _____

   _____ (1)

   (c) Iron is used in the Haber Process as a catalyst. Explain how iron functions as a catalyst in this reaction.

   _____

   _____

   _____ (2)

(Total: 4 marks)

SECTION B
Answer ALL questions in this section.

9. Amino acids have two organic functional groups. One of the simplest amino acids is 2-aminopropanoic acid or alanine.
   (a) Draw the structure of 2-aminopropanoic acid.

   (1)

   (b) One of the carbons atoms in 2-aminopropanoic acid is a chiral carbon. Circle the chiral carbon in your drawing in 9(a). (1)

   (c) What type of isomerism is exhibited by molecules having a chiral carbon?

   _____ (1)

   (d) How are optical isomers distinguished from each other?

   _____

   _____

   _____ (1)

This question continues on the next page.

(e) Amino acids in the solid state are composed of zwitterions. Draw the zwitterion for aminopropanoic acid.

(1)

(f) Write a balanced equation to show the change in the zwitterion when an acid is added to it.

_____

_____

_____ (1)

(Total: 6 marks)

10. (a) BF_3 and NH_3 are both polyatomic molecules and each one of the molecules has a total of 4 atoms.

(i) Draw the molecular shape of each molecule.

(2)

(ii) State the name of the geometrical shape and write the bond angle in each case.

_____

_____ (2)

(b) Explain the following statement: Although both diamond and graphite are macromolecules of carbon, only graphite conducts electricity.

_____

_____

_____

_____ (2)

(Total: 6 marks)

11. (a) Draw the molecular structure of the organic compounds A and B.

(i) A: butan-2-ol B: butanoic acid

(1)

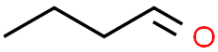
(ii) Describe a chemical test to distinguish between compounds A and B and state observations.

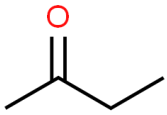
_____

_____

_____ (1½)

(b) (i) Name the following organic compounds C and D.

C: 

D: 

_____

_____ (1)

(ii) Describe a chemical test which can distinguish between compounds C and D and state observations.

_____

_____

_____ (1½)

(c) Primary alcohols can be oxidised to both aldehydes and carboxylic acids. In each case, specific conditions are required. List these conditions for each case.

_____

_____

_____ (1)

(Total: 6 marks)

12. (a) What is understood by the term saturated vapour pressure.

_____

_____

_____ (2)

This question continues on the next page.

(b) How does an increase in temperature affect the saturated vapour pressure?

_____

_____ (1)

(c) A vapour which forms above the surface of a liquid L in a closed container exerts a pressure of 1.25×10^5 Nm^{-2} and occupies a volume of 1500 cm^3 at a temperature of 27 ˚C. Calculate the number of moles of the vapour.

_____

_____

_____

_____ (3)

(Total: 6 marks)

13. (a) Alkanes are saturated hydrocarbons, while alkenes and alkynes are unsaturated hydrocarbons. Explain the following terms.

(i) hydrocarbon: _____

_____ (½)

(ii) saturated: _____

_____ (1)

(iii) unsaturated: _____

_____ (1)

(b) Typically, alkanes undergo substitution reactions while alkenes undergo addition reaction. Give a suitable example for each.

Substitution: _____ (1)

Addition: _____ (1)

(c) Propene reacts with hydrogen chloride. Give the structural formula and the name of the major product.

_____

_____

_____

_____ (1½)

(Total: 6 marks)

SECTION C

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

14. (a) (i) Define the enthalpy change of combustion. (2)

(ii) Write the chemical reaction for the enthalpy change of combustion of methane. (2)

(iii) The bond enthalpy terms for the following bonds are:

Bond	Bond enthalpy term ($kJmol^{-1}$)
C – H	413
O – H	464
O = O	498
C = O	805

Thus, estimate the enthalpy change of combustion of methane. (4)

(iv) The experimental value of the standard enthalpy change of combustion of methane was found to be -890.3 $kJmol^{-1}$. Explain why this is different from the value obtained in (a)(iii). State which value is more reliable, and explain why. (3)

(b) Enthalpy changes of combustion can be used to determine enthalpy changes of formation.

(i) Write the equation for the standard enthalpy change of formation of butane. (2)

(ii) Given that the standard enthalpy changes of combustion for carbon (graphite), hydrogen and butane are –394 $kJmol^{-1}$, –286 $kJmol^{-1}$ and –2877 $kJmol^{-1}$ respectively, calculate the standard enthalpy change of formation of butane. (7)

(Total: 20 marks)

15. (a) "The Haber process for the manufacture of ammonia is an example of an industrial application of a reversible process".

(i) Write the chemical equation for the Haber process, including state symbols. (2)

(ii) Give the expression for K_c for this reaction and state its units. (2)

(iii) The equilibrium concentrations of nitrogen, hydrogen and ammonia are 0.025 $moldm^{-3}$, 0.050 $moldm^{-3}$ and 0.035 $moldm^{-3}$ respectively at a given temperature. Calculate the value of K_c at this temperature. (3)

(iv) Given the value of the equilibrium constant at the given temperature, comment about the position of equilibrium. (2)

(v) Explain the difference in the position of equilibrium, if any, if the pressure on the equilibrium mixture is increased, while keeping the temperature constant. (3)

(b) With reference to the equilibrium reaction in (a), explain the following statements:

(i) There are two reactions in an equilibrium reaction, and it is a dynamic equilibrium. (2)

(ii) If we start with nitrogen and hydrogen gas only, and keeping a constant temperature, the rates of the two reactions change until equilibrium is reached. (3)

(iii) If we start with given concentrations of nitrogen and hydrogen gas only, and keeping a constant temperature, the concentrations change until equilibrium is reached. (3)

(Total: 20 marks)

Please turn the page.

16. (a) Acids and bases are defined in different ways.
    (i) Give the definition of an Arrhenius acid and an Arrhenius base. (2)
    (ii) Give the Brønsted-Lowry definition of an acid and a base. (2)
    (b) Use the Brønsted-Lowry definitions of an acid and a base to explain the following.
    (i) Ethanoic acid (CH_3COOH) dissolves in water. Write the chemical equation of the reaction that takes place and identify the acid, the base, the conjugate acid and the conjugate base. (3½)
    (ii) Ammonia (NH_3) dissolves in water. Write the chemical equation of the reaction that takes place and identify the acid, the base, the conjugate acid and the conjugate base. (3½)
    (iii) Considering the above two reactions involving ethanoic acid and ammonia, explain the acid-base nature of water. (2)
    (c) Water dissociates slightly into H^+ and OH^- ions, as shown by the following equation:

$$H_2O\ (l) \rightleftharpoons H^+\ (aq) + OH^-\ (aq)$$

    (i) Derive an expression for the ionic product of water, K_w. (3)
    (ii) Given that the value of K_w at 25 $^\circ$C is 1.0×10^{-14}, find the pH of a 0.001 moldm^{-3} aqueous sodium hydroxide solution. (4)

(Total: 20 marks)

17. (a) Condider the following two half equations involving manganate(VII) ions to manganese(II) ions in an acidic solution, and iron(II) to Fe(III) respectively.

$$MnO_4^-\ (aq) + 5e^- + 8H^+\ (aq) \rightarrow Mn^{2+}\ (aq) + 4H_2O\ (l)$$
$$Fe^{2+}\ (aq) \rightarrow Fe^{3+}\ (aq) + e^-$$

    A redox titration involving manganate(VII) – iron(II) is carried out.
    (i) Give the overall ionic equation for the redox reaction taking place in this titration. (2)
    (ii) The actual titration was carried out with potassium manganate(VII), sulfuric acid solution and iron(II) chloride. Explain why the potassium, the sulfate and the chloride ions do not feature in the equation. (2)
    (iii) Find the oxidation number of each element in the reaction and state what is oxidized and what is reduced. (7)
    (iv) An tablet of mass 0.960 g containing iron(II) ions was dissolved in dilute sulfuric acid. A redox titration with 0.0180 moldm^{-3} potassium manganate(VII) solution gave an average titre value of 28.50 cm^3 to reach the endpoint. Calculate the percentage by mass of iron in the tablet. (5)
    (b) A volume of 50.0 cm^3 of 0.025 moldm^{-3} of an iron(II) chloride solution was mixed with 40.0 cm^3 of 0.015 moldm^{-3} of a solution of acidified potassium manganate(VII) chloride solution.
    (i) Determine the limiting reagent. (3)
    (ii) Calculate the maximum number of moles of Mn^{2+} (aq) formed. (1)

(Total: 20 marks)

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PERIODIC TABLE

Key: Relative atomic mass — A; X; Z — Atomic Number

I	II											III	IV	V	VI	VII	VIII
1 H 1																	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															

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