L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE
EXAMINATIONS BOARD

**INTERMEDIATE MATRICULATION LEVEL
2023 SECOND SESSION**

SUBJECT:	**Chemistry**
DATE:	5th September 2023
TIME:	4:00 p.m. to 7:05 p.m.

Useful information
Relative atomic masses: Na = 23, Cl = 35.5, Fe = 56
A Periodic Table is included.

SECTION A
Answer ALL questions in this section.

1. Neon has three main isotopes, Ne-20, Ne-21 and Ne-22, with relative abundances of 90.5%, 0.27% and 9.25% respectively. Find its relative atomic mass, giving your answer to one decimal place.

_____

_____

_____

_____ (3)

(Total: 3 marks)

2. Consider period 3 of the Periodic Table. There are variations in properties of the elements across a period. Indicate how, across a period, from sodium to argon, how the following trends vary.

   (a) Boiling point: _____

_____ (1)

   (b) Atomic radius: _____

_____ (1)

   (c) Valency: _____

_____ (1)

(Total: 3 marks)

Please turn the page.

3. (a) Write the electronic configuration, in spdf notation, of the following elements:

    (i)   beryllium: _____ (1)

    (ii) nitrogen: _____ (1)

    (iii) argon: _____ (1)

    (b) Write the electronic configuration of nitrogen by using the electrons-in-boxes notation.

    _____ (1)

    (Total: 4 marks)

4. (a) Chlorate(I) can be used as a bleaching agent or a disinfectant. Write the formula of the chlorate(I) (or hypochlorite) ion.

    _____ (1)

    (b) Find the oxidation number of chlorine in the chlorate(I) ion.

    _____

    _____ (1)

    (c) Iodine is used in titrimetry. Write the ionic equation for the reaction between iodine $[I_2(aq)]$ and thiosulfate solution $[S_2O_3^{2-}(aq)]$.

    _____

    _____ (2)

    (Total: 4 marks)

5. State the separation technique that needs to be used to separate the two components in the following cases:

    (a) A mixture of water and sand.

    _____ (1)

    (b) A solution of sodium chloride.

    _____ (1)

    (c) A mixture of ethanol and water.

    _____ (1)

    (d) A mixture of solid sodium chloride and solid iodine.

    _____ (1)

    (Total: 4 marks)

6. (a) Explain the term electronegativity.

_____

_____

_____ (2)

(b) There is unequal electron sharing, and bond polarization, in a molecule of hydrogen chloride. Explain.

_____

_____

_____ (2)

(Total: 4 marks)

7. A solution was formed by dissolving 11.7 g of sodium chloride in 200 cm^3 of solution. Calculate the concentration of the sodium chloride solution in $moldm^{-3}$.

_____

_____

_____

_____

_____

_____

_____

_____ (4)

(Total: 4 marks)

8. (a) What colour is observed when a flame test is carried out on salts with the following metal ions?

(i) Sodium ion: _____ (1)

(ii) Potassium ion: _____ (1)

(b) Give a test to identify the presence of carbonate ions.

_____

_____

_____ (2)

(Total: 4 marks)

Please turn the page.

SECTION B

Answer ALL questions in this section.

9. (a) Consider the chemical reaction: H_2 (g) + $\frac{1}{2}O_2$ (g) $\rightarrow$ H_2O (g)
       Given the bond enthalpy terms below, calculate the ΔH for the reaction.
       [H−H] = 432 kJmol^{-1}
       [O=O] = 496 kJmol^{-1}
       [H−O] = 463 kJmol^{-1}

_____

_____

_____

_____

_____

_____ (4)

    (b) Sketch an energy (enthalpy) level diagram for the reaction in part (a) above.

(2)

(Total: 6 marks)

10. (a) Consider the chemical reaction: $2H_2O_2 \rightarrow 2H_2O + O_2$
Using oxidation numbers, indicate what is being oxidized and what is being reduced. Show your reasoning.

_____

_____

_____

_____

_____ (4)

   (b) (i) Name this 'special' type of redox reaction.

_____ (1)

     (ii) Explain what happens in such a redox reaction.

_____

_____

_____ (1)

(Total: 6 marks)

11. (a) One can distinguish between propanal and propanone by reacting with acidified potassium dichromate(VI) solution. Explain, giving chemical reactions wherever necessary.

_____

_____

_____

_____ (2)

   (b) Both aldehydes and ketones have a common chemical group although they have different functional groups. Explain.

_____

_____ (1)

   (c) (i) Hydrogen cyanide reacts with aldehydes and ketones to produce compounds known as hydroxynitriles; it interacts with the group mentioned in part (b). Write down the equations to represent these reactions; use propanal and propanone as examples in your answer.

_____

_____

_____

_____ (2)

DO NOT WRITE ABOVE THIS LINE

(ii) What is the type of reaction taking place in part (c)(i) called?

_____ (1)

(Total: 6 marks)

12. (a) Consider the reaction: X (g) + Y (g) → Z (g).
    (i) Sketch a graph showing the change of concentration of X with time. On the same set of axes, plot the change of concentration of Z with time. Label the axes of the graph appropriately.

(3)

    (ii) Given that this reaction is endothermic, sketch the reaction profile for this reaction. Label the axes of the graph appropriately.

(2)

    (b) If the pressure is increased on the reaction mixture, what would be the effect on the rate of the reaction?

_____

_____ (1)

(Total: 6 marks)

13. (a) Consider the reaction: $CH_4 (g) + 2O_2 (g) \rightarrow CO_2 (g) + 2H_2O (g)$

A volume of 300 cm^3 of methane were mixed with 800 cm^3 of oxygen. The reaction was left to go to completion. All volumes were measured at the same temperature and pressure.

(i) Calculate the volume of carbon dioxide produced.

_____

_____

_____ (1½)

(ii) Calculate the volume of water vapour produced.

_____

_____

_____ (1½)

(b) What is the total volume of gas after the reaction goes to completion?

_____

_____

_____

_____

_____ (3)

(Total: 6 marks)

Please turn the page.

SECTION C

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

14. This question is about acids, bases and buffers.
    (a) Acids and bases are found all around us, e.g., citric acid in oranges, and baking soda. Solutions of acids and bases can have different concentrations and be of different strengths. One measure of these solutions is their pH.
        (i) What does the pH of a solution measure? (1)
        (ii) What is the pH of a solution containing 1×10^{-4} moldm^{-3} hydrogen ions? Is this solution acidic or alkaline? (3)
        (iii) The pH of 0.010 moldm^{-3} hydrochloric acid is 2. State whether the pH of 0.010 moldm^{-3} CH_3COOH is greater than 2, smaller than 2 or equal to 2 and explain your reasoning. (5)
        (iv) A student was told that a solution labelled X was formed by the addition of 25cm^3 of 0.010 moldm^{-3} sulfuric(VI) acid to 30cm^3 of 0.10 moldm^{-3} sodium hydroxide solution. Calculate the pH of solution X. (5)
        (v) How could the student find the pH value of solution X in the chemistry laboratory? (1)

    (b) Human blood contains several buffer systems. One of the most important is the carbonic acid (H_2CO_3) and hydrogen carbonate anion (HCO_3^-) buffer system.
        (i) Explain why a buffering system in the blood is essential. (2)
        (ii) Explain how **ONE** of the buffer systems in the blood works. (3)
   **(Total: 20 marks)**

15. This question is about transition metals and volumetric analysis.
    (a) Transition metals and their compounds can act as catalysts. The effect of a catalyst on the activation energy of a reaction can be shown in a graph of the distribution of molecular energies of a gas.
        (i) Explain how a catalyst affects a chemical reaction which goes to completion. (2)
        (ii) Sketch a distribution curve for the molecular energies in a gas at a fixed temperature. (In this graph, plot Fraction of Molecules on the y-axis and Energy on the x-axis). (2)
        (iii) On the same graph, mark the activation energy for a non-catalysed reaction as E_a(NON-CAT) and the activation energy of the catalysed reaction as E_a(CAT). (2)
        (iv) On the same graph, indicate with crosses the proportion of molecules that react in the non-catalysed reaction and indicate with dots the proportion of molecules that react in the catalysed reaction. (2)

    (b) Transition metals have variable oxidation states. An element in different oxidation states has different coloured ions.
        (i) Identify the colour of the $[Cu(H_2O)_6]^{2+}$ ion and the oxidation state of copper in this ion. (1½)
        (ii) Write the formula of the ion which gives a deep blue colouration when an excess of aqueous ammonia is added to a sample of copper(II) sulfate(VI) solution, and state the oxidation state of copper in this ion. (1½)
        (iii) When aqueous sodium hydroxide is added to a green solution of iron nitrate, a green precipitate forms. On standing (in the presence of air), this green precipitate darkens to a brown colour. Identify the ions which are responsible for the green solution of iron nitrate, the green precipitate and the brown precipitate. (3)

(c) Purple potassium manganate (VII) can be used to estimate the amount of iron(II) ions. A chemist needed to estimate the iron content in a mineral supplement tablet. A tablet weighing 0.9 g, was dissolved in dilute sulphuric acid and was titrated with a solution of 0.02 $moldm^{-3}$ potassium manganate(VII) solution. A titre of 18 cm^3 of potassium permanganate was required to reach the end-point.

The equation for the reaction is:

$$5\ Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$$
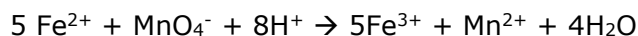
(i) Identify the oxidising agent in the above reaction of MnO_4^- and Fe^{2+} ions. (½)

(ii) Potassium manganate(VII) acts as its own indicator. Explain this statement and describe the colour of the solution in the flask during the titration and at the endpoint. (2½)

(iii) Calculate the number of moles of potassium permanganate that were required in the titration. (½)

(iv) Calculate the number of moles of iron(II) present in the tablet. (1)

(v) Calculate the percentage by mass of iron in the tablet. (1½)

(Total: 20 marks)

16. This question is about alkenes, alcohols and polymers.

*Please use structural formulae and not general molecular formulae throughout your answer*.

(a) Alkenes undergo electrophilic additions. But-1-ene reacts with hydrogen chloride to form a major product P and a minor product Q. Both P and Q have a general formula of C_4H_9Cl.

(i) Explain why alkenes undergo electrophilic addition reactions. (1)

(ii) Write a balanced equation (using structural formulae) to show the production of compound P. (2)

(iii) In the above reaction of but-1-ene with hydrogen chloride, compound P is produced in large quantities through a particular addition process. Explain this statement with reference to both the production of compound P and of compound Q. (2)

(iv) Compound R is an isomer of but-1-ene. When compound R reacts with hydrogen chloride, it produces only compound P as a product. Write the structural formula of R. (1)

(v) Why does compound R produce only one product in the reaction described in part (iv) above? (2)

(vi) What type of isomerism do compounds P and Q represent? (1)

(b) But-1-ene can be converted to an alcohol S. Alcohol S can also be converted to the compound P (mentioned above) with the molecular formula C_4H_9Cl.

(i) Write a balanced equation for the conversion of but-1-ene to the alcohol S and state the reagents and conditions which are required for the reaction. (2½)

(ii) Write the reagent and conditions which are required to convert alcohol S to compound P. (1)

(iii) Alcohol S is oxidised to compound T. A student wanted to confirm the identity of compound T by testing T with blue Fehling's reagent. State, with reasons, the expected observations in this test and the conclusions with respect to the identity of compound T. (2½)

The question continues on the next page.

(c) Polylactic acid (PLA) is a polyester made from monomers with difunctional groups. The monomer which is used for PLA is lactic acid (2-hydroxypropanoic acid). The formula of lactic acid is $CH_3CHOHCOOH$.

(i) Draw the molecular structure of the lactic acid monomer, and mark clearly (with a circle) the hydrogen and the oxygen atoms which are lost from each monomer when polymerisation occurs. (2)

(ii) PLA has several applications especially in the packaging and in the market of medical devices. Explain the differences in the type of polymerisation between PLA and polythene in terms of their environmental impact. (2½)

(iii) Which one of the two polymers, PLA or polyethene is much more biodegradable? (½)

(Total: 20 marks)

17. This question requires knowledge on chemical equilibria, on the esterification reaction and the Haber Process.

(a) The esterification reaction between ethanoic acid and ethanol is a reversible reaction. The equation for this reaction is:

$$CH_3COOH + CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3 + H_2O$$
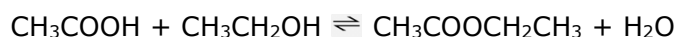
(i) The above reaction can be split into a forward reaction and a backward reaction. Give an equation for the backward reaction. (1)

(ii) The above reaction reaches dynamic equilibrium after several hours. Explain this statement. (3)

(iii) Chemists would be interested to increase the yield of one of the substances in a reversible reaction by changing one or some of the conditions. The change can be predicted using Le Chatelier's principle. State Le Chatelier's principle. (2)

(iv) Discuss what happens to the equilibrium position and to the yield of the ester if a dehydrating agent is added to the above reversible reaction. (2)

(v) A reagent which is added as a dehydrating agent acts also as a catalyst in this reversible reaction. Name this reagent and explain its catalytic role in a reversible reaction. (4)

(b) The production of ammonia by the Haber process is affected by the factors of temperature, pressure, catalysts and concentration. The forward reaction in the production of ammonia is exothermic.

(i) Write a balanced equation with state symbols for the reaction of nitrogen and hydrogen to produce ammonia. (2)

(ii) Explain, by referring to Le Chatelier's principle, the effect of increasing the pressure and the effect of increasing the temperature on the yield of ammonia. (4)

(iii) Identify a vital product which is synthesised from ammonia on a large scale and explain the importance of such products to the world economy. (2)

(Total: 20 marks)

DO NOT WRITE ABOVE THIS LINE

DO NOT WRITE ABOVE THIS LINE

DO NOT WRITE ABOVE THIS LINE

PERIODIC TABLE

Key

	A
	X
	Z

Relative atomic mass — A
Atomic Number — Z

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