Index Number:_____ IM06.22s

L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

INTERMEDIATE MATRICULATION LEVEL
2022 SECOND SESSION

SUBJECT:	**Chemistry**
DATE:	2nd September 2022
TIME:	4:00 p.m. to 7:05 p.m.

Useful information
Ideal gas constant = 8.314 $JK^{-1}mol^{-1}$
Relative atomic masses: C = 12, O = 16, Ca = 40.
A Periodic Table is included.

SECTION A
Answer ALL questions in this section.

1. Consider the nuclear equation: $^{A}_{92}X \rightarrow {}^{228}_{Z}Y + \alpha$
   (a) Find the values of A and Z.

_____

_____ (2)

   (b) If the half-life of the radioactive element X for α-decay is 4 years, what percentage of its total initial activity will it have after 12 years?

_____

_____ (1)

(Total: 3 marks)

2. Propene reacts with hydrogen chloride to give chloropropane.
   (a) Write a chemical equation to represent this reaction.

_____ (1)

   (b) There are two possible products, but as indicated by a particular rule, one product predominates. Name and explain this rule.

_____

_____

_____

_____

_____ (2)

(Total: 3 marks)

3. Consider the elements in period 2 of the Periodic Table, Li to Ne.
   (a) Explain the term periodicity.

_____

_____

_____ (1)

   (b) Explain each of the following.
      (i) The valency changes across the period.

_____

_____

_____ (1)

      (ii) The first ionisation energy changes across the period. Use a graph/diagram to enhance your explanation.

_____

_____

_____

_____

_____ (2)

(Total: 4 marks)

4. (a) State Avogadro's law.

_____

_____ (1)

   (b) Hydrogen gas reacts with oxygen gas to give steam, at a high temperature.
      (i) Write a balanced equation, including state symbols, for this reaction.

_____ (1)

      (ii) There is enough oxygen gas so that a volume of 10 cm^3 of hydrogen gas reacts completely to produce steam. Calculate the volume of steam produced. Show your working.

_____

_____

_____ (2)

(Total: 4 marks)

5. A compound is composed of carbon, hydrogen and oxygen only. The percentages of each element in the compound are: 40.0% carbon, 6.7% hydrogen, and 53.3% oxygen.
   (a) Find the empirical formula.

_____

_____

_____

_____ (2½)

   (b) If the relative molecular mass of the compound is 180, find its molecular formula.

_____

_____

_____ (1½)

(Total: 4 marks)

6. Consider the following reaction mechanism for the reaction between ethene and hydrogen bromide:

$$C_2H_4 + HBr \rightarrow C_2H_5^+ + Br^- \rightarrow C_2H_5Br$$

   (a) The reaction occurs in two steps, one of which is faster than the other. Explain.

_____

_____

_____ (2)

   (b) What is the slower step called?

_____ (1)

   (c) What is this type of reaction called?

_____ (1)

(Total: 4 marks)

Please turn the page.

7. Calcium carbonate solid reacts with hydrochloric acid solution.

(a) (i) Write the chemical equation, including state symbols, for this reaction.

_____ (1)

(ii) Write the ionic equation for this reaction.

_____ (1)

(iii) The chemical equation and the ionic equation for the reaction between calcium carbonate and hydrochloric acid are different. Explain, indicating what is meant by the term spectator ions.

_____

_____

_____

_____ (2)

(Total: 4 marks)

8. (a) The hydrogen halides can be prepared from their salts. Explain and include a chemical equation.

_____

_____

_____ (2)

(b) Not all the aqueous solutions of the hydrogen halides give strong acids. Explain.

_____

_____

_____ (2)

(Total: 4 marks)

SECTION B

Answer ALL questions in this section.

9. [In] Condensation polymerization … molecules combine, losing small molecules as by-products such as water or methanol. It produces linear polymers from bifunctional monomers. … A common example of condensation polymerization is the esterification of carboxylic acids with alcohols.

(Source: http s://plasticranger.com/what-is-condensation-polymerization/)

(a) Explain each of the following terms:

(i) bifunctional; _____

_____ (1)

(ii) condensation. _____

_____ (1)

(b) Consider the reaction between the acid and the alcohol below.

(i) Write the equation for the reaction between the acid and the alcohol above.

(2)

(ii) Draw the structural formula of the repeating unit of the product (containing the two monomers).

(2)

(Total: 6 marks)

Please turn the page.

10. The boiling points of water, hydrogen sulfide, and methane (at STP) are 100 ^{O}C, -60 ^{O}C and -162 ^{O}C respectively.
    (a) Indicate the physical state of **each** of the three substances at room temperature.

_____

_____ (1½)

    (b) Indicate the predominant intermolecular forces present in **each** case.

_____

_____ (1½)

    (c) Explain the very high differences in boiling point between the three substances.

_____

_____

_____

_____

_____

_____ (3)

(Total: 6 marks)

11. Consider the following reversible reaction: a mixture of nitrogen gas and hydrogen gas gives ammonia gas.
    (a) Write a balanced equation for this reversible reaction, including state symbols.

_____ (2)

    (b) Indicate the shift of equilibrium for **each** of the following changes:
        (i) An increase in the concentration of hydrogen gas.

_____ (1)

        (ii) A decrease in pressure.

_____ (1)

        (iii) The introduction of a suitable catalyst such as iron.

_____ (1)

        (iv) An increase in temperature. The reaction between nitrogen and hydrogen to gives ammonia is exothermic.

_____ (1)

(Total: 6 marks)

12. Consider the following acid-base reaction:

$$CH_3COOH\ (aq) + H_2O\ (l) \rightleftharpoons CH_3COO^-\ (aq) + H_3O^+\ (aq)$$

(a) According to the Bronsted-Lowry theory, indicate the:

(i) acid: _____ (½)

(ii) base: _____ (½)

(iii) conjugate acid: _____ (½)

(iv) The conjugate base: _____ (½)

(b) A solution of hydrochloric acid and a solution of sulfuric acid are found to have the same concentration of 0.01 $moldm^{-3}$. Explain, by carrying out the necessary calculations, why although they have the same concentration, they have a different pH.

_____

_____

_____

_____

_____ (4)

(Total: 6 marks)

13. (a) The melting point of a sample of liquid A, thought to be water, has a boiling point of 100.7 ^{O}C.

(i) What can be concluded about liquid A?

_____ (1)

(ii) If liquid A were to be frozen, and its melting point measured, predict a value for its melting point.

_____ (1)

(b) A substance can be extracted out of a solution using another solvent. The process is called solvent extraction. The extraction occurs because compounds have a 'choice' of two solvents that they can dissolve in.
Outline the method, indicating the apparatus used and the characteristics of the two solvents.

_____

_____

_____

_____

_____

_____ (4)

(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 the standard heat of formation and bond energies.

(a) The standard heat of formation of ethane can be calculated from standard enthalpies of combustion. The following list gives the standard enthalpies of combustion of some substances in kJ mol^{-1}.

Standard enthalpies of combustion in $kJmol^{-1}$	
C (s)	-394
H_2 (g)	-286
C_2H_6 (g)	-1550

(i) Define the term standard heat of formation. (2)

(ii) Write an equation, including state symbols, which represents the standard heat of formation of ethane. (2)

(iii) Draw an energy cycle (Hess's cycle) which shows the relationship between the standard heat of formation of ethane and the enthalpies of combustion which are given in the above list. (4)

(iv) Use Hess's cycle and the above data for the enthalpies of combustion to calculate the standard heat of formation of ethane. (3)

(b) Ethane can be formed via the hydrogenation of ethene according to the following equation.

$C_2H_4 + H_2 \rightarrow C_2H_6$

(i) Rewrite the above equation, giving the structural formulae to show the (types of) bonds that are present between all the atoms in the molecules of ethene, hydrogen and ethane. (3)

(ii) Use the standard bond enthalpies in the following list to calculate the standard heat of reaction for the hydrogenation of ethene. (4)

Standard bond enthalpies in $kJmol^{-1}$	
C – C	348
C = C	614
C – H	413
H – H	436

(iii) Explain why the value of a heat of reaction obtained from bond enthalpies (as above) is **not** accurate. (2)

(Total: 20 marks)

15. This question is about shapes of molecules and bonding in substances.
    (a) Both molecules of boron trifluoride (BF_3) and ammonia are composed of four atoms, i.e., they are of the type AX_3.
        (i) Draw the shapes of these two molecules and state the values of the angles. (2)
        (ii) Name the shapes of the molecules. (2)
        (iii) Explain why the shapes of the two molecules are different. (1)
    (b) Both ammonia and water have abnormally high boiling points due to a particular type of intermolecular bonding.
        (i) Name this type of bonding. (1)
        (ii) Draw a diagram showing this type of bonding in water. Include at least two molecules of water in your diagram. (2)
        (iii) Describe how this type of intermolecular bonding forms. (2)
    (c) The following substances have different types of bonding: sodium chloride, copper, silicon dioxide, oxygen.
        (i) Consider the above substances and write the type of bonding in each case. (2)
        (ii) Discuss which of the above substances are expected to have relatively high boiling points and which, in the solid state, conduct electricity. Use diagrams to illustrate your answer. (8)

    (Total: 20 marks)

16. This question is about the chemistry of five organic compounds A, B, C, D and E.
    Compound A and compound B are functional group isomers of molecular formula C_3H_6O. Compound A can be oxidized to an acidic compound C and reduced to compound D. Compound B does not undergo a similar oxidizing reaction, but both compounds A and B react with HCN to form hydroxynitriles. Compound D and compound E are also isomers, but not functional group isomers. Compound E can be oxidised to compound B.
    You may use the following working space to organise your ideas and draw a scheme for the above reactions. This scheme will not be marked.

Working Space

Please turn the page.

(a) (i) What is understood by functional group isomers? (2)
(ii) Identify the classes of compounds A and B. (2)
(iii) What type of isomers are compounds D and E? (1)
(iv) Name compounds D and E. (2)

(b) (i) Write chemical equations that represent the reactions of A to C and B to E. (2)
(ii) Name the reagents and give the conditions which are required in the above two reactions. (2)

(c) (i) Write an equation to show the reaction of compound A with HCN. (1)
(ii) Explain why sodium or potassium cyanide and a small amount of sulfuric(VI) acid is often used instead of hydrogen cyanide. (1)
(iii) The hydroxynitrile which is obtained in the reaction in part c(i) can be hydrolysed. Draw the structure of the product in this hydrolysis reaction. (1)

(d) Compound D can be converted into compound C.
(i) Would compound D be oxidized or reduced to compound C in the reaction? (1)
(ii) What conditions and reagents would you use to form C from D? (1)

(e) Both compounds C and D react with PCl_5. This reaction indicates the presence of a particular chemical group in the two different compounds.
(i) Name the chemical group which is indicated by the above PCl_5 reaction. (1)
(ii) What would you observe in the separate reactions of compounds C and D with PCl_5? (1)
(iii) Describe a reaction which distinguishes between compounds C and D. (2)

(Total: 20 marks)

17. This question is about quantitative analysis.

(a) A sample of pure calcium carbonate weighing 3 g was heated strongly until the reaction was completed. The equation for the reaction is: $CaCO_3\,(s) \rightarrow CaO\,(s) + CO_2\,(g)$
(i) Calculate the number of moles of calcium carbonate. (1)
(ii) Calculate the expected number of moles of carbon dioxide. (1)
(iii) In this experiment, 650 cm^3 of carbon dioxide was collected over water. Considering the molar volume of gases to be 24 $dm^3\ mol^{-1}$ under experimental conditions, calculate the percentage yield of the gas. (4)

(b) In another experiment, a piece of limestone weighing 0.5 g reacted with 100 cm^3 of 0.1 $moldm^{-3}$ hydrochloric acid. The acid was in excess. This excess acid was exactly neutralized by 12 cm^3 of 0.1 $moldm^{-3}$ sodium hydroxide solution.

The calcium carbonate which is present in limestone reacts with hydrochloric acid according to the following equation:

$CaCO_3\,(s) + 2HCl\,(aq) \rightarrow CaCl_2\,(aq) + CO_2(g) + H_2O\,(l)$

(i) Write a chemical equation, with state symbols, which represents the reaction of sodium hydroxide and the excess acid. (1)
(ii) Calculate the number of moles of sodium hydroxide which were needed to neutralize the excess acid. (1)
(iii) Calculate the number of moles of acid which did **not** react with the calcium carbonate in the limestone. (2)
(iv) Calculate the number of moles of hydrochloric acid which reacted with the calcium carbonate in the limestone. (4)
(v) Calculate the number of moles of calcium carbonate in the limestone. (3)
(vi) Calculate the percentage purity of calcium carbonate in the limestone. (3)

(Total: 20 marks)

DO NOT WRITE ABOVE THIS LINE

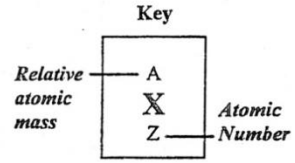
DO NOT WRITE ABOVE THIS LINE

DO NOT WRITE ABOVE THIS LINE

DO NOT WRITE ABOVE THIS LINE

DO NOT WRITE ABOVE THIS LINE

PERIODIC TABLE



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