**MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD**

**UNIVERSITY OF MALTA, MSIDA**

**MATRICULATION EXAMINATION**
**INTERMEDIATE LEVEL**
**MAY 2017**

| | |
|---|---|
| **SUBJECT:** | CHEMISTRY |
| **DATE:** | 30th May 2017 |
| **TIME:** | 4:00 p.m. to 7:05 p.m. |

Useful information: 1 mol of any gas or vapour occupies 22.4 $dm^3$ at s.t.p.
Relative atomic masses: H = 1, C = 12, O = 16, Na = 23
Avogadro's Number = $6 \times 10^{23}$
A Periodic Table is included.

## SECTION A

**Answer ALL questions in this section.**

1. (a) An atom consists of sub-atomic particles: protons, neutrons and electrons. Complete the following table, giving the number of particles and writing the species as an isotopic notation in the second row of the species column.

| | Species | Number of | | |
|---|---|---|---|---|
| | | protons | neutrons | electrons |
| (i) | $^{24}_{12}Mg^{2+}$ | 12 | | |
| (ii) | $^{4+}$ | 22 | 26 | |

(2)

(b) An atom has half as many protons as an atom of $^{28}Si$ and also has six fewer neutrons than an atom of $^{28}Si$. Give the symbol, including the mass number and the atomic number of this atom.

_____

_____ (1)

**(Total: 3 marks)**

2. Atoms gain or lose electrons to form ions.
   (a) Give the electron configuration using the s, p and d notation for the calcium cation.

_____ (½)

***This question continues on next page.***

(b) Write the symbol and charge of **TWO** anions which are isoelectronic with the calcium cation.

_____ (1)

(c) Write the **THREE** isoelectronic ions in parts (a) and (b) in order of increasing nuclear charge.

_____ (½)

(d) Write the following in order of increasing first ionisation energies, starting with the one with the lowest ionisation energy: Li, F, Na, N.

_____ (1)

**(Total: 3 marks)**

3. (a) Explain the term electronegativity.

_____

_____ (1)

(b) The table below gives the electronegativity values of some elements.

| | Fluorine | Chlorine | Bromine | Aluminium | Sodium |
|---|---|---|---|---|---|
| Electronegativity | 4.0 | 3.0 | 2.8 | 1.6 | 0.8 |

Explain how these values can be used to predict the bonding in:

(i) sodium bromide (NaBr);

_____

_____ (½)

(ii) aluminium chloride ($AlCl_3$).

_____

_____ (½)

(c) Complete the following sentences:

(i) The bonding in sodium bromide is _____. (½)

(ii) The bonding in aluminium chloride is _____. (½)

(d) Explain why the electronegativity value of fluorine is higher than the electronegativity value of chlorine.

_____

_____

_____ (1)

**(Total: 4 marks)**

4. (a) List **THREE** main types of intermolecular forces, in order of their strength, starting with the weakest type of forces.

_____

_____ (1½)

(b) The following table shows the boiling points of some substances.

| | **$F_2$** | **$CH_3F$** | **HF** |
|---|---|---|---|
| Boiling point in K | 85 | 194 | 293 |

(i) Explain why the three substances in the table have different boiling points.

_____

_____

_____

_____ (1½)

(ii) How does the strongest type of intermolecular force in liquid HF arise?

_____

_____ (1)

**(Total: 4 marks)**

***Please turn the page.***

5. The decomposition of ammonia into nitrogen and hydrogen was studied at 623 K. It was found that the equilibrium constant in terms of concentration for this reversible process was 0.45 $mol^2dm^{-6}$.

(a) Give an equation which represents the decomposition of ammonia.

_____ (1)

(b) Write an expression of $K_c$ for this reaction.

_____

_____ (1)

(c) In a second experiment at 623 K, some ammonia was heated for a set time and the composition of the mixture was found to be as follows:
$[N_2 (g)]$ = 0.04 $moldm^{-3}$, $[H_2 (g)]$ = 0.03 $moldm^{-3}$ and $[NH_3 (g)]$ = 0.02 $moldm^{-3}$.
Did the reaction in the second experiment reach equilibrium? Show your reasoning or calculation.

_____

_____

_____ (2)

**(Total: 4 marks)**

6. (a) The monomer 2-chloropenta-1,4-diene can give an addition polymer.

(i) Draw the structure of 2-chloropenta-1,4-diene.

(½)

(ii) Explain the term addition polymer.

_____

_____

_____

_____ (1)

(b) In the monomer 2-chloropenta-1,4-diene, the double bond between the first carbon atom and the second carbon atom is used in the formation of the polymer. The double bond between the fourth carbon atom and the fifth carbon atom remains a double bond and forms part of the side-group of the polymer unit.

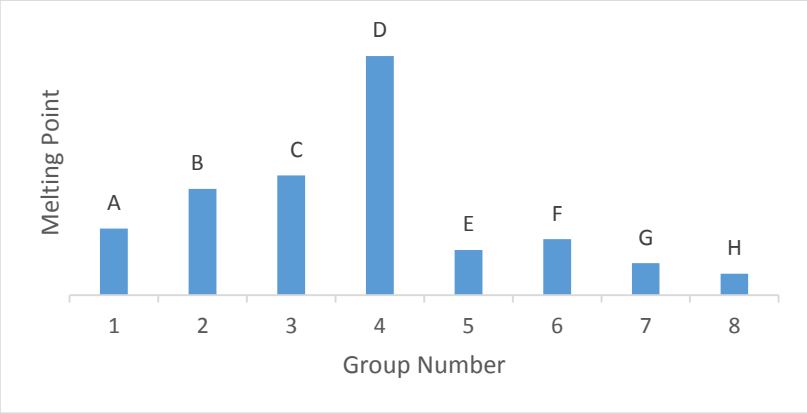
(i) Draw a section of the polymer consisting of **THREE** repeating units.

(2)

(ii) Draw a circle around **ONE** of the three repeating units in part (b)(i). (½)

**(Total: 4 marks)**

7. The following graph shows the melting points of the elements in Period 3. The letters A to H represent different elements.




(a) Name the type of bonding present in elements A and B.

A: _____ B: _____ (1)

(b) Suggest why the melting point in element B is higher than that of element A.

_____

_____

_____

_____ (2)

***This question continues on next page.***

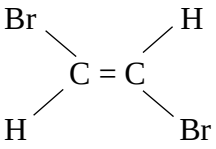
(c) Elements D and E are both covalently bonded. In terms of structure, account for the large difference in their melting points.

_____

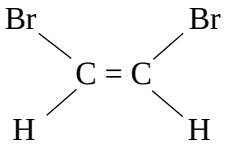
_____ (1)

**(Total: 4 marks)**

8. X and Y are isomers with the formula $C_2H_2Br_2$. The structures of X and Y are drawn below.




**X**




**Y**

(a) Z is another isomer of X and Y. Draw its structural formula and label it Z.

(½)

(b) Name the compounds X, Y, and Z.

X: _____ Y: _____

Z: _____ (1½)

(c) What type of isomerism exists between isomers X and Y?

_____ (1)

(d) What type of isomerism exists between Y and Z?

_____ (1)

**(Total: 4 marks)**

## SECTION B

**Answer ALL questions in this section.**

9. (a) Which of the following three substances contains the fewest molecules? Show your reasoning.

(i) 0.5 g of hydrogen ($H_2$); (ii) 4.0 g of oxygen ($O_2$); and (iii) 11.0 g of carbon dioxide ($CO_2$).

_____

_____

_____

_____

_____ (2)

(b) Which one of the above contains the greatest number of atoms? Show your reasoning.

_____

_____ (1)

(c) A snowflake is described as a feathery ice crystal. It is made of water. How many molecules of water are there in a snowflake weighing 0.5 mg?

_____

_____ (1)

(d) What is the volume occupied by $3.6 \times 10^{22}$ molecules of water vapour at s.t.p.?

_____

_____

_____ (2)

**(Total: 6 marks)**

***Please turn the page.***

10. The equations below show the reactions between:
    - water and a hydrogen cation: $H_2O + H^+ \longrightarrow H_3O^+$; and
    - boron trifluoride and a fluoride anion: $BF_3 + F^- \longrightarrow BF_4^-$.

(a) Draw diagrams to show the shape of: (i) $H_2O$; (ii) $BF_3$; (iii) $H_3O^+$; and (iv) $BF_4^-$.

(4)

(b) In terms of the electrons involved, explain how:

(i) the bond between $H_2O$ and $H^+$ is formed;

_____

_____ (1)

(ii) the bond between $BF_3$ and $F^-$ is formed.

_____

_____ (1)

**(Total: 6 marks)**

11. (a) A 0.25 g sample of sodium metal was added to 200 $cm^3$ of water. The following reaction occurred:

$$Na\ (s) + H_2O\ (l) \longrightarrow NaOH\ (aq) + \tfrac{1}{2}H_2\ (g)$$

(i) Calculate the number of moles of sodium taking part in the reaction.

_____

_____ (½)

(ii) Calculate the molarity of the sodium hydroxide solution which was formed.

_____

_____ (1)

(b) In another experiment 25 $cm^3$ of 0.183 $moldm^{-3}$ sodium hydroxide were neutralised by 13.7 $cm^3$ of sulphuric(VI) acid.

(i) Write a fully balanced equation for the reaction.

_____ (2)

(ii) Calculate the molarity of the sulphuric(VI) acid.

_____

_____

_____

_____ (2½)

**(Total: 6 marks)**

***Please turn the page.***

12. Hydrogen reacts with both chlorine and iodine. The activation energies for these reactions are:

$H_2$ (g) + $Cl_2$ (g) $\longrightarrow$ 2HCl (g) $E_a$ = 25 kJmol$^{-1}$

$H_2$ (g) + $I_2$ (g) $\longrightarrow$ 2HI (g) $E_a$ = 157 kJmol$^{-1}$

(a) Which reaction will be faster at a particular temperature? Explain your answer.

_____

_____ (2)

(b) Explain the effect of an increase in pressure on the rate of the reaction for the reaction of hydrogen and chlorine.

_____

_____ (2)

(c) Explain the effect of an increase in temperature on the rate of the reaction for the reaction of hydrogen and chlorine.

_____

_____

_____ (2)

**(Total: 6 marks)**

13. This question is about purification techniques.

(a) The boiling point of bromoethane is 38 $^{o}$C and the boiling point of ethanol is 78 $^{o}$C.

(i) Name the process which can be used to separate the components of a mixture containing bromoethane and ethanol.

_____ (1)

(ii) Explain why this process is the most suitable?

_____ (1)

(b) Benzoic acid is soluble in hot water and insoluble in cold water.

(i) Name the process which is used to separate benzoic acid from a solution containing impurities which are soluble in cold water.

_____ (1)

(ii) Describe the purification process.

_____

_____

_____

_____

_____ (3)

**(Total: 6 marks)**

## SECTION C

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

14. The values of the standard enthalpy change of combustion for methane gas, carbon solid and hydrogen gas are indicated in the table below.

| | $\Delta H°_c$ (kJ $mol^{-1}$) |
|---|---|
| $CH_4$ (g) | -802 |
| C (s) | -394 |
| $H_2$ (g) | -286 |

(a) Define the term standard enthalpy change of combustion. Indicate clearly what is meant by the word standard. (3)

(b) Give the chemical equations that correspond to standard enthalpy change of combustion of methane, carbon and hydrogen; include state symbols. (4)

(c) Define the term standard enthalpy change of formation. (2)

(d) Give the chemical equation that correspond to the standard enthalpy change of formation of methane; include state symbols. (2)

(e) Use the above information to construct a Hess' law cycle. (5)

(f) Thus calculate the standard heat of formation of methane. (4)

**(Total: 20 marks)**

***Please turn the page.***

15. (a) Hydrochloric acid is a strong acid while ethanoic acid is a weak acid.
    (i) Distinguish between strong and weak acids. (1)
    (ii) Explain briefly why one can write the acid dissociation constant $K_a$ of ethanoic acid, but the $K_a$ of hydrochloric acid does not make sense. (2)
    (iii) Write the chemical equation that corresponds to the dissociation of ethanoic acid. Hence write the equation for the acid dissociation constant $K_a$ of ethanoic acid, and indicate its units. (3)

    (b) An aqueous solution of ethanoic acid actually represents an acid-base reaction. According to the Bronsted-Lowry theory, this reaction includes an acid, a base, a conjugate acid and a conjugate base.
    (i) Define acid and base according to the Bronsted-Lowry theory. (1)
    (ii) Write the chemical equation that represents this acid-base reaction. (1)
    (iii) Indicate the acid, the base, the conjugate acid and the conjugate base in this reaction. (2)
    (iv) Hydrochloric acid actually reacts with ethanoic acid. Write the chemical equation for this reaction, and indicate the acid, the base, the conjugate acid and the conjugate base. (3)
    (v) Both hydrochloric acid and ethanoic acid are normally considered as acids, and usually acids react with bases and not with other acids. Explain briefly why these two acids actually react. (2)

    (c) Chemists speak of the constant $K_w$, the ionic product of water.
    (i) Give the equation for $K_w$, and indicate the units of $K_w$. (2)
    (ii) The numerical value of $K_w$ at 25 $^oC$ is $1 \times 10^{-14}$. This value is the same for a sample of pure water and for a sample of aqueous acid. Explain briefly. (2)
    (iii) What can be done to change the value of $K_w$? (1)

**(Total: 20 marks)**

16. Explain the following statements. Chemical equations should be given wherever appropriate.
    (a) The compounds of transition metals are coloured, and transition metals show variable oxidation states. Illustrate your answer by giving **ONE** suitable example in each case. (5)
    (b) Transition metals and their compounds show catalytic properties. This can be shown with $MnO_2$ in the decomposition of hydrogen peroxide, and Raney nickel in the hydrogenation of unsaturated hydrocarbons. (5)
    (c) The metal-ligand bonding in coordination compounds can be described in terms of dative covalent (coordinate) bonding. (5)
    (d) The complex ions $[Fe(H_2O)_6]^{2+}$, $[Cu(NH_3)_4]^{2+}$ and $[CuCl_2]^-$ have different shapes. This can be deduced from the electron pair repulsion theory. (5)

**(Total: 20 marks)**

17. (a) (i) The compound with molecular formula $C_2H_6O$ can have two different functional groups. Explain, indicating the **TWO** homologous series. (2)

(ii) The boiling points of the two compounds in part (i) are quite different. Explain why. (2)

(iii) The compound with molecular formula $C_3H_6O$ can be in two different homologous series. Explain. (2)

(iv) The two compounds in part (iii) can be distinguished through a simple chemical test. Explain. (2)

(b) There are primary, secondary and tertiary alcohols.

(i) Distinguish between primary, secondary and tertiary alcohols. (3)

(ii) Primary, secondary and tertiary alcohols can be distinguished through oxidation. Explain. (3)

(iii) Ethanol can be dehydrated to ethene or to ethoxyethane. Explain. (3)

(iv) Give the chemical reaction for the esterification reaction between ethanol and ethanoic acid. Give any necessary conditions for the reaction to occur. (3)

**(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 |