MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
INTERMEDIATE LEVEL
MAY 2016

SUBJECT:	CHEMISTRY
DATE:	23rd May 2016
TIME:	9:00 a.m. to 12:05 p.m.

Useful information: One mole of any gas occupies 22.4 dm^3 at standard temperature and pressure
Relative atomic masses: H = 1, C = 12, N = 14, O = 16

A Periodic Table is included.

Section A
Answer ALL questions in this Section

1. (a) In the following Table, give the molar mass and the molar volume at 0°C and 101325 Nm^{-2} for the two gases carbon dioxide and ammonia.

	Molar Mass	**Molar Volume at 0°C and 101325 Nm^{-2}**
Carbon Dioxide		
Ammonia		

(2 marks)

(b) State the volume of oxygen required for the complete combustion of 1 dm^3 of methane. All gas volumes are measured at 0°C and 101325 Nm^{-2}.

$$CH_4 \text{ (g)} + 2O_2 \text{ (g)} \rightarrow CO_2 \text{ (g)} + 2H_2O \text{ (g)}$$
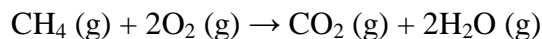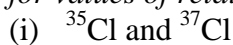
(1 mark)
Total: 3 marks

2. Mark each of the following statements as **True** or **False**.

| (a)	The vapour pressure of a liquid increases with a decrease in temperature.	
(b)	The boiling point of a liquid is the temperature at which its saturated vapour pressure equals the pressure of the atmosphere.	
(c)	The more volatile the liquid, the more energy is required to evaporate one mole of the liquid.	

Total: 3 marks

3. Consider the following three pairs of atoms and/or ions. They differ in the number of sub-atomic particles. Explain the difference within each pair. *You may refer to the Periodic Table provided for values of relative atomic mass and atomic number.*
    (i) ^{35}Cl and ^{37}Cl

(1 mark)

  (ii) ^{16}O and $^{16}O^{2-}$

(1 mark)

  (iii) $^{39}K^+$ and $^{40}Ca^{2+}$
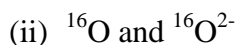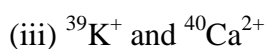
(1 mark)
Total: 3 marks

4. (a) (i) Write the **group number** in the periodic table (e.g. Group VII) **_or_** the **group name** (e.g. halogens), for each of the following elements.

Description	Group
The element with electronic configuration $1s^22s^22p^63s^23p^4$	
An element whose uni-negative anion has the electronic configuration $1s^22s^22p^63s^23p^6$	
An element which has 21 neutrons and a mass number of 40	
An element with atomic number 18	

(2 marks)

  (ii) Complete the following statement: An element with an electronic configuration of

  [Ar]$3d^64s^2$ is a _____ _____.   (1 mark)

  (b) The ions N^{3-}, O^{2-}, F^-, Na^+, Mg^{2+} and Al^{3+} form an isoelectronic series.
       (i) Explain the meaning of the term *isoelectronic*.

  (ii) Identify the smallest ion in the series and give a reason for your choice.

(2 marks)
Total: 5 marks

5. Benzene is described as having a system of delocalised electrons.
    (a) Draw a diagram representing the molecular structure of benzene, and in the diagram mark clearly the feature that represents the delocalised electrons.

(1 mark)

    (b) Describe how the carbon atoms in benzene are bonded together.

(3 marks)
Total: 4 marks

6. Alkanes burn readily and react rapidly with free radicals produced by the action of ultraviolet light on chlorine or bromine molecules.
    (a) Write a balanced equation for the complete combustion of liquid hexane. Include state symbols in your equation.

(1 mark)

    (b) Write a balanced equation for the formation of bromine free radicals in an alkane bromination reaction.

(1 mark)

    (c) Write **two** equations to show how bromine free radicals react with hexane to form 1-bromohexane.

(2 marks)
Total: 4 marks

7. Ethanol reacts with 2-methylbutanoic acid to produce an ester which is found in apples.
    (a) Draw the structural formula of: (i) ethanol; and (ii) 2-methylbutanoic acid.

(2 marks)

    (b) Write a balanced equation for the formation of the ester. In the equation, give the structural formula of the ester.

(2 marks)
Total: 4 marks

8. A student carried out the investigation of a white powder labelled **Salt A** and a green powder labelled **Salt B**. The student prepared a solution of the salts and then proceeded with some tests. She made the following observations:

Salt A	
Test: Addition of	**Result**
Water	Salt dissolved; colourless solution formed
NaOH (aq)	A white precipitate is formed; the precipitate dissolved in excess NaOH (aq)
NH$_3$ (aq)	A white precipitate is formed; the precipitate dissolved in excess NH$_3$ (aq)
Dilute nitric acid and silver nitrate solution followed by a few drops of NH$_3$ (aq)	A white precipitate is formed; the precipitate dissolved in a small quantity of NH$_3$ (aq)

Salt B	
Test: Addition of	**Result**
Water	Salt dissolved; a pale green solution formed
NaOH (aq)	A dark mud-green precipitate is formed; the precipitate slowly turned brown at the surface
NH$_3$ (aq)	A dark mud-green precipitate is formed; the precipitate slowly turned brown at the surface
Barium chloride followed by dilute hydrochloric acid	A white precipitate is formed

    (a) Identify the cation and the anion in **Salt A**.

(2 marks)

    (b) Identify the cation and the anion in **Salt B**.

(2 marks)
Total: 4 marks

Section B
Answer ALL questions in this Section

9. An alkane contains 83% carbon and 17% hydrogen by mass.
    (a) What is its empirical formula?

(2 marks)

(b) When 20 cm^3 of the alkane in part 9(a) were burnt in 200 cm^3 of oxygen (an excess), the residual gases occupied 150 cm^3. On shaking with aqueous potassium hydroxide, this volume decreased to 70 cm^3. (All gas volumes were measured at room temperature and pressure).
    (i) Calculate the volume of carbon dioxide in the residual mixture.

(2 marks)

    (ii) What is the molecular formula of the alkane?

(2 marks)
Total: 6 marks

10. The compounds of formula C_4H_{10} exhibit isomerism. The two isomers of formula C_4H_{10} have different boiling points: one isomer has a boiling point of **-11.6^oC** and the other's boiling point is **-0.4^oC**.

(a) State which type of isomerism is exhibited by the isomers of formula C_4H_{10}.

(1 mark)

(b) Draw and name the two isomers with formula C_4H_{10}.

(2 marks)

(c) Assign the appropriate boiling point to each isomer, and explain your reasoning.

(3 marks)
Total: 6 marks

11. (a) List the main types of intermolecular forces associated with simple molecules and indicate the relative strength of these forces.

(3 marks)

(b) Propanol, propanal and butane have similar relative molecular masses. Explain why propanol is very soluble in water, propanal is less soluble and butane is insoluble.

(3 marks)
Total: 6 marks

12. (a) In the space below, draw, with labelled axes, a curve to represent the distribution of molecular kinetic energies of a sample of a gas at a given temperature. Label this curve T_1. On the same axes, draw a second curve to represent the distribution of molecular energies in the sample of gas at a **lower** temperature. Label this curve T_2.

(2 marks)

(b) Use these curves to explain why a small decrease in temperature can lead to a large decrease in the rate of the reaction.

(1 mark)

(c) Give **two** reasons why most collisions between gas-phase reactants do not lead to a reaction.

(2 marks)

(d) State **two** ways of increasing the rate of a gas-phase reaction other than by changing the temperature.

(1 mark)
Total: 6 marks

13. (a) State what would be observed when:
    (i) chlorine gas is bubbled into an aqueous solution of potassium iodide;

(1 mark)
    (ii) drops of concentrated sulfuric(VI) acid are added to solid sodium chloride; and

(1 mark)
    (iii) drops of concentrated sulfuric(VI) acid are added to solid sodium bromide.

(1 mark)
    (iv) Give the balanced equation for the reaction in part (ii).

(1 mark)
    (b) Chlorine is frequently added to drinking water. Explain this statement referring to the ion formed, and how it makes water suitable for drinking.

(2 marks)
Total: 6 marks

Section C
Answer TWO questions from this Section

14. (a) Define the terms 'acid' and 'base' according to the Bronsted-Lowry theory.

(1 mark)

(b) Consider the following reaction:
$$CH_3COOH \text{ (aq)} + HNO_3 \text{ (aq)} \rightleftharpoons CH_3COOH_2^+ \text{ (aq)} + NO_3^- \text{ (aq)}$$
Identify the acid, the base, the conjugate acid and the conjugate base.

(4 marks)

(c) The concentration of an aqueous solution of calcium hydroxide is 0.005 moldm^{-3}.
   (i) Find the concentration of hydroxide ions.

(2 marks)

   (ii) Give the equation for the ionic product of water. Give its numeric value, and indicate its units.

(3 marks)

   (iii) Find the hydrogen ion concentration in the aqueous calcium hydroxide solution.

(3 marks)

   (iv) Find the pH of the aqueous calcium hydroxide solution.

(3 marks)

(d) (i) Calcium hydroxide is an alkali. Explain briefly why '*all alkalis are bases, but not all bases are alkalis*'.

(2 marks)

   (ii) Consider solutions of 0.05 moldm^{-3} hydrochloric acid and 0.5 moldm^{-3} ethanoic acid. Referring to these two acids, explain the difference between concentration and strength.

(2 marks)
Total: 20 marks

15. (a) Consider the following equilibrium reaction:

$$N_2 \text{ (g)} + 3H_2 \text{ (g)} \rightleftharpoons 2NH_3 \text{ (g)} \qquad \Delta H = -92.4 \text{kJmol}^{-1}$$
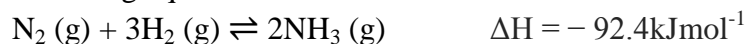
   (i) Write the equation for K_p for this equilibrium reaction.

(3 marks)

   (ii) Give the units of K_p. Show the working.

(2 marks)

   (iii) The value of K_p for this equilibrium reaction, at a temperature of 500°C, is 1.45 x 10^{-5}. In an equilibrium mixture of the three gases at 500°C, the partial pressure of hydrogen is 0.93 atm and the partial pressure of nitrogen is 0.43 atm. Calculate the partial pressure (in atm) of ammonia in the equilibrium mixture.

(6 marks)

   (iv) If one considers that 1 atm is equivalent to 100,000 Pa, convert the value of the partial pressure of ammonia to Pa.

(1 mark)

   (b) Consider the above equilibrium reaction involving nitrogen, hydrogen and ammonia, and its ΔH value.

   (i) Give the name of this industrial process.

(1 mark)

   (ii) Give typical values of the pressure and the temperature adopted for this industrial process.

(2 marks)

   (iii) Predict the shift in equilibrium, if any, if the pressure on the equilibrium mixture is increased. Explain briefly.

(2 marks)

   (iv) Predict the shift in equilibrium, if any, if the temperature of the equilibrium mixture is increased. Explain briefly.

(3 marks)
Total: 20 marks

16. (a) (i) Define the standard enthalpy change of formation. Give the equation for the enthalpy change of formation of methane.

(1 mark + 1 mark)

(ii) Define the standard enthalpy change of combustion. Give the equations for the enthalpy change of combustion of carbon and of hydrogen.

(1 mark + 2 marks)

(iii) Join the three equations (enthalpy change of formation of methane, enthalpy change of combustion of carbon and of hydrogen) into a Hess' cycle.

(3 marks)

(iv) Using the cycle in part (a)(iii), calculate the enthalpy change of combustion of methane, if:

enthalpy change of formation of methane $= -75 kJmol^{-1}$
enthalpy change of combustion of carbon $= -394 kJmol^{-1}$
enthalpy change of combustion of hydrogen $= -286 kJmol^{-1}$.

(5 marks)

(b) The following information was found on the 'Calorie checker' – within the 'NHS Choices' web pages – of the National Health Service in the UK.

"*The bolognese sauce contains . . .*
- *280g of dried . . . spaghetti . . . 100g of dried spaghetti . . . 348kcal (1,454kJ).*
- *200g of lean beef mince . . . the raw mince contains 171kcal (715kJ) per 100g.*
- *two cans of 400g of chopped tomatoes . . . each can contains 96kcal.*
- *one onion . . . a medium raw onion contains 55kcal.*
- *two carrots . . . a carrot contains 35kcal.*
- *a tablespoon of olive oil for frying . . . this contains 119kcal.*
- *vegetable stock, herbs and spices – the calorie content is almost zero . . . ignored. . . .*"

(http://www.nhs.uk/Livewell/weight-loss-guide/Pages/calorie-counting.aspx)

(i) Considering the data for '*dried spaghetti*' and '*raw mince*', calculate an average value for the equivalent of 1 calorie in J. Give your answer to **two places of decimal**.

(2 marks)

(ii) How many kJ would one consume if s/he eats a serving, that is a quarter of the recipe above.

(5 marks)
Total: 20 marks

17. (a) Define the following terms:
  (i) 'oxidation' and 'reduction' in terms of reaction with oxygen and hydrogen.
  (2 marks)
  (ii) 'oxidation' and 'reduction' in terms of transfer of electrons.
  (2 marks)
  (iii) 'oxidation' and 'reduction' in terms of oxidation number.
  (2 marks)

(b) Sodium reacts with chlorine to give sodium chloride:
$$2Na\ (s) + Cl_2\ (g) \rightarrow 2NaCl\ (s)$$
  (i) Give the oxidation half equation for the above redox reaction.
  (1 mark)
  (ii) Give the reduction half equation for the above redox reaction.
  (1 mark)

(c) Sodium chloride solution is added to a solution of silver nitrate.
  (i) Give the equation, including state symbols, for this reaction.
  (2 marks)
  (ii) Give the ionic equation for this reaction.
  (2 marks)
  (iii) Using oxidation numbers, deduce whether this is a redox reaction or not. Explain your reasoning.
  (2 marks)

(d) The following reaction is said to be a disproportionation reaction:
$$3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$$
  (i) Using oxidation numbers, indicate what is being oxidized and what is being reduced.
  (4 marks)
  (ii) Explain briefly why it is a disproportionation reaction.
  (2 marks)
  Total: 20 marks

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PERIODIC TABLE

Key

	A	
	X	
	Z	

Relative atomic mass → A

X → 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