Index No:_____ **IM 06.13s**

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
INTERMEDIATE LEVEL
SEPTEMBER 2013

SUBJECT:	CHEMISTRY
DATE:	7th September 2013
TIME:	9.00 a.m. to 12.00 noon

Useful information: One mole of any gas or vapour occupies 22.4 dm^3 at s.t.p.
The molar gas constant R = 8.31 J K^{-1} mol^{-1}.
Relative atomic masses: H=1; C=12; N=14; O=16; Na=23; S=32; Cl=35.5; K=39

A Periodic Table is included.

Section A
Answer all questions in this Section

1. Ammonia may be produced by the reaction:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92kJmol^{-1}$$

Indicate (by writing increase or decrease) what changes in pressure, temperature and concentration of nitrogen will result in an increase in the amount of ammonia produced:

Pressure: _____

Temperature: _____

Concentration of nitrogen: _____ (3 marks)

2. Zinc reacts with aqueous copper sulfate according to the equation:

$$Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s)$$

(a) Identify the species that is oxidised in this reaction. _____ (1 mark)

(b) Identify the species that is reduced in this reaction. _____ (1 mark)

(c) Identify the *spectator ion*. _____ (1 mark)

(d) Explain the meaning of the term *spectator ion*.

_____

_____(1 mark)

Total: 4 marks

3. The *first electron affinity* of sulfur is -200 $kJmol^{-1}$.

(a) Explain the term *first electron affinity*.

_____(2 marks)

(b) Give an equation to represent the first electron affinity of sulfur.

_____(2 marks)

Total: 4 marks

4. This question concerns the following organic compounds:

A	$CH_3CH_2COOCH_3$
B	$CH_3CH_2CH_2COOH$
C	$CH_3CH_2CH_2CH_2OH$
D	$CH_3CH_2COCH_3$

Select from **A** to **D** the compound/s which:

(a) may be produced by the treatment of a secondary alcohol with acidified potassium dichromate solution. _____

(b) may be formed by a reaction between an alcohol and a carboxylic acid.

_____

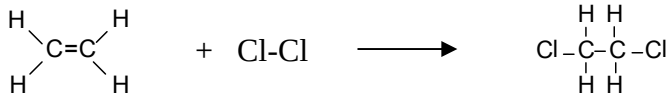
(c) react/s with PCl_5 to produce fumes of HCl. _____

(d) form/s an aqueous solution with a pH value less than 7.

_____

Total: 5 marks

5. Ethene reacts with chlorine according to the following equation:



Use the bond enthalpies (in $kJmol^{-1}$) listed below to calculate the enthalpy change for the reaction between ethene and chlorine.

C-C 348 C-Cl 338 C=C 612 Cl-Cl 242

(7 marks)

6. A compound is made up of the elements potassium (28.2%), chlorine (25.6%) and oxygen (46.2%). Determine the empirical formula of this compound.

(5 marks)

7. Calculate the volume occupied by 2.00 g of carbon monoxide at 25^{o}C and a pressure of 17500 Nm^{-2}.

(6 marks)

8. Calculate the mass of oxygen produced when 8.5 g of sodium nitrate(V), $NaNO_3$, is completely decomposed according to the equation:

$$2NaNO_3(s) \longrightarrow 2NaNO_2(s) + O_2(g)$$

(5 marks)

9. Draw the structure of the organic molecules indicated in the table. Show all the atoms and bonds present.

propene	
butane	
benzene	
ethanol	

(4 marks)

10. (a) Give an equation for the reaction between propene and HBr.

_____ (2 marks)

(b) Draw the structure of the main product expected.

(2 marks)

Total: 4 marks

11. Describe, giving reactants, reaction conditions and an equation, how:

(a) propene may be converted into propane;

Reactants _____

Reaction conditions _____

Equation _____ (3 marks)

(b) ethyne may be obtained from a reaction involving a calcium compound.

Reactants _____

Reaction conditions _____

Equation _____ (3 marks)

Total: 6 marks

12. The compound ethene may undergo addition polymerization.

(a) Give the structure of the repeating unit of the polymer.

_____ (2 marks)

(b) State the name of the polymer.

_____ (1 mark)

(c) State one use of the polymer.

_____ (1 mark)

Total: 4 marks

13. This question concerns techniques (crystallization, fractional distillation, solvent extraction, filtration, chromatography) that are used to separate and purify substances. For each of the applications described below, choose the appropriate method of separation.

(a) Separation of pigments in natural colours. _____ (1 mark)

(b) Obtaining different products from petroleum. _____ (1 mark)

(c) Obtaining a solid ionic solute from its aqueous solution. _____ (1 mark)

(d) Obtaining a solid covalent solute from its aqueous solution; the solute decomposes on heating. _____ (1 mark)

(e) Collecting a precipitate formed in an aqueous solution. _____ (1 mark)

Total: 5 marks

14. The element phosphorus is in Group 5 of the Periodic Table. It forms a chloride of formula PCl_3.

(a) Draw a dot-and-cross diagram of a molecule of PCl_3.

(2 marks)

(b) Draw the 3-dimensional shape of PCl_3.

(2 marks)

(c) State whether the pH of the solution obtained when PCl_3 reacts with water is expected to be 7, greater than 7 or less than 7.

_____ (1 mark)

(d) Briefly describe how periodicity is shown in the behaviour of the chlorides with water on going from left to right across the Periodic Table.

_____

_____

_____

_____ (4 marks)

Total: 9 marks

15. (a) From the elements listed below, choose the element that is most likely to have successive ionisation energies of 786, 1580, 3230, 4360, 16 000, 20 000 $kJmol^{-1}$. Underline the element and give a reason for your choice.

A. aluminium B. magnesium C. phosphorus D. silicon E. sodium

Reason:

_____

_____ (3 marks)

(b) The first ionisation energy of magnesium is lower than the first ionisation energy of the element:

A. aluminium B. sodium C. potassium D. calcium E. beryllium

Reason:

_____

_____ (3 marks)

(c) The first and second ionisation energies of element **Q** are 740 and 1500 $kJmol^{-1}$ respectively. Write an equation to represent the first and second ionization energies.

First ionization energy of **Q**: _____

Second ionization energy of **Q**: _____ (3 marks)

Total: 9 marks

Section B

Answer all questions in this Section

16. This question is about alkanes and their uses.

(a) Octane is a member of the homologous series called alkanes. Draw the structure of octane.

(3 marks)

(b) Octane is a component of petrol. Compare the use of octane with hydrogen, stating four advantages and/or disadvantages of these fuels.

(8 marks)

(c) *Cracking* of decane ($C_{10}H_{22}$) may be used to produce octane.

(i) Explain the term *cracking*.

(2 marks)

(ii) Under which conditions may cracking take place?

(2 marks)

(iii) Name a useful organic molecule that is expected as a by-product of cracking of decane in the production of octane. _____ (1 mark)

Total: 16 marks

17. The elements fluorine, chlorine, bromine, iodine and astatine are in Group 7 of the Periodic Table.

(a) State the name given to this group of the Periodic Table.

_____(1 mark)

(b) Write down the names or symbols of the elements chlorine, bromine and iodine in order of:

(i) atomic size (smallest first);

_____ (2 marks)

(ii) reactivity (slowest first).

_____ (2 marks)

(c) Give a reason for the order given in (b)(i) and (b)(ii).

(i) Reason for order of atomic size:

_____

_____

_____(2 marks)

(ii) Reason for order of reactivity:

_____

_____

_____(2 marks)

(d) Chlorine is a useful substance that is manufactured on a large scale.

(i) Name a substance that is usually used as the raw material for the production of chlorine.

_____(1 mark)

(ii) Name the process that may be used to obtain chlorine from this raw material.

_____(1 mark)

(iii) Give one use of chlorine.

_____(1 mark)

(e) Hydrogen chloride may be prepared in the laboratory by the action of concentrated sulfuric acid on sodium chloride.

(i) Give an equation for the reaction.

_____(2 marks)

(ii) Explain why this method cannot be used for the laboratory preparation of hydrogen bromide or hydrogen iodide.

_____

_____(2 marks)

Total: 16 marks

18. Read each statement given below and state whether it is **true** or **false** giving a reason for your answer.

(a) In a crystal of potassium bromide each potassium ion forms only one ionic bond with the bromide ion it donated its electron to.

_____

_____

_____(3 marks)

(b) On going from sodium to chlorine across the Periodic Table, the atomic radius decreases.

_____

_____

_____

_____(4 marks)

(c) The rmm of H_2S is greater than the rmm of H_2O therefore the boiling point of H_2S is greater than the boiling point of H_2O.

_____

_____

_____(4 marks)

(d) The reason why ionic substances are solids while many covalent substances are liquids or gases is because ionic bonds are strong while covalent bonds are weak.

_____

_____

_____

_____(5 marks)

Total: 16 marks

19. The mass spectrometer is an instrument that may be used to determine relative atomic and molecular masses.

(a) A sample of substance **X** is injected as a gas into the ionization chamber. State what happens in the ionization chamber. Give an equation to represent the change occurring to **X**.

_____

_____

_____(3 marks)

(b) After ionization, the sample is accelerated and then passed through a magnetic field. State what happens when the sample passes through the magnetic field.

_____

_____(2 marks)

(c) Explain the following terms related to mass spectrometry.

(i) molecular ion _____

(ii) fragmentation _____

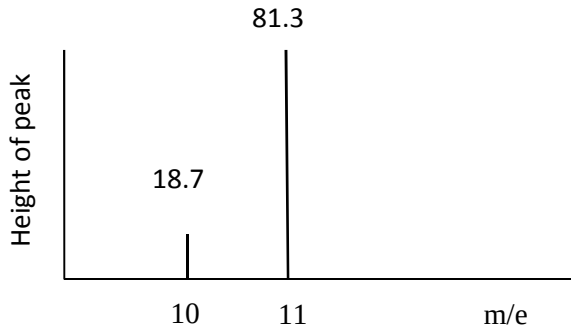
(iii) height of peak _____(3 marks)

(d) The mass spectrum of a sample of chlorine gas shows three peaks at m/e 70, 72 and 74. Given that chlorine occurs as isotopes with mass numbers 35 and 37, state what each peak represents.

m/e 70 _____ m/e 72 _____

m/e 74 _____ (3 marks)

(e) The mass spectrum of a sample of boron is given below. Work out the relative atomic mass of boron.



(5 marks)

Total: 16 marks

20. This question is about atoms and their structure.

(a) An atom of the element aluminium may be represented by: $^{27}_{13}Al$.

(i) In the space given below, sketch an atom of aluminium indicating the **position** of the protons, neutrons, electrons and the nucleus.

(5 marks)

(ii) Fill in the table with details about $^{27}_{13}Al$.

atomic number	
mass number	
number of neutrons	
number of electrons	
number of protons	
electronic configuration of $^{27}_{13}Al$ (using spdf notation)	
electronic configuration of the stable ion expected from $^{27}_{13}Al$ (using spdf notation)	
formula of the stable ion expected from $^{27}_{13}Al$	

(8 marks)

(b) Some atoms are radioactive. Name the part of the atom responsible for radioactivity during emission of:

(i) α-particles _____

(ii) β-particles _____

(iii) γ-radiation _____

(3 marks)

Total: 16 marks

Please turn the page for Section C

Section C

Answer TWO questions from this Section

Write your answers on the lined pages provided.

21. During a school practical, students carried out an acid-base titration. They were given two reagent bottles containing 250 cm^3 of hydrochloric acid solution of concentration 1.5 $moldm^{-3}$ and 200 cm^3 of sodium hydroxide solution of unknown concentration respectively.

    According to the procedure sheet, after washing the glassware they had to fill the burette with the hydrochloric acid solution and then place 25.0 cm^3 of sodium hydroxide in a conical flask, add two to three drops of indicator to the flask, and titrate the solution.

    The procedure had to be repeated until at least two concordant results were obtained. A student actually carried out five titrations.

    The results that that the student obtained are reported in the table below:

Titration number	**1**	**2**	**3**	**4**	**5**
Final reading (cm^3)	23.40	46.20	22.50	45.00	27.50
Initial reading (cm^3)	0.00	23.40	0.00	22.50	5.00
Titre value (cm^3)					

(a) (i) Outline the washing procedure for the burette, the bulb pipette and the conical flasks. (6 marks)

(ii) Explain briefly why the indicator is added to the contents of the conical flask before the titration. Mention a suitable indicator for this acid-base titration exercise. (3 marks)

(iii) How is the end-point detected? (2 marks)

(iv) What is the significance of the end-point? (2 marks)

(v) Why is the titration repeated a number of times? (2 marks)

(vi) What is meant by the term concordant results? (2 marks)

(b) The aim of this titration exercise was to find the concentration, in $moldm^{-3}$, of the sodium hydroxide solution.

(i) Write the chemical equation, including state symbols, of the reaction between hydrochloric acid and sodium hydroxide solution. (3 marks)

(ii) Write the ionic equation, including state symbols, that represents the same reaction. (3 marks)

(iii) Work out the titre value for each of the five titrations reported in the table. (5 marks)

(iv) Calculate the average titre value to be used in the remaining part of the calculation leading to the unknown concentration. (2 marks)

(v) Calculate the number of moles of hydrochloric acid involved in the reaction. (4 marks)

(vi) How many moles of sodium hydroxide react with this number of moles of hydrochloric acid? Show your reasoning. (2 marks)

(vii) Calculate the concentration of the sodium hydroxide solution. (4 marks)

Total: 40 marks

22. (a) A flame test was carried out on three white solids **A**, **B** and **C** and they gave a yellow/orange flame, a brick red flame and a lilac flame respectively. A colourless solution **D** was also flame-tested and a light apple green colour was obtained.

When some drops of sulfuric acid were added to around 1 cm^3 of solution **D** in a test tube, a white precipitate was obtained.

Other tests were carried out as indicated below:

- To around 1 cm^3 of a solution of **A**, barium chloride solution was added giving a white precipitate. On adding hydrochloric acid to the test tube contents, a gas **E** with a choking smell was given; gas **E** turned acidified potassium dichromate green.

- The solid **B** was insoluble in water. When dilute hydrochloric acid was added onto a sample of solid **B**, effervescence was noted. The gas **G** produced turned lime water milky.

- To about 1 cm^3 of an aqueous solution of **C**, some drops of solution **D** were added and a white precipitate was produced. On addition of hydrochloric acid to the test tube contents, there was no visible reaction.

- Some dilute nitric acid and successively a few drops of silver nitrate solution were added to about 1 cm^3 of solution **D**. A white precipitate was given, which dissolved in ammonia solution.

(i) Identify the compounds **A**, **B** and **C**. (3 x 3 marks)
(ii) Identify the compound contained in solution **D**. (4 marks)
(iii) Identify gases **E** and **G**. (2 marks)
(iv) Give the ionic equation, including state symbols, for the reaction of solid **B** with hydrochloric acid. (4 marks)
(v) Give the ionic equation, including state symbols, for the reaction between the precipitate given by **A** (in the reaction between a solution of **A** and barium chloride solution) and hydrochloric acid. (4 marks)

(b) Four reagent bottles, each containing **a colourless solution**, were marked **W**, **X**, **Y** and **Z** respectively.

For each of the four solutions, about 1 cm^3 of the solution was poured into a test tube and a few drops of sodium hydroxide solution were added. A white precipitate was given in each test tube.

Then, more sodium hydroxide solution was added into each test tube after the white precipitate appeared. The outcome of the addition of excess sodium hydroxide solution is shown in the table below.

The same procedure was repeated with ammonia solution. Once again, onto about 1 cm^3 of each of the four solutions in four different test tubes, a few drops of ammonia solution were added. A white precipitate was given in each case. Then more ammonia solution was added into each test tube after the white precipitate appeared; the outcome of the addition of excess ammonia solution is also reported in the table below.

Solution	**+ excess NaOH (aq)**	**+ excess NH_3 (aq)**
W	insoluble	insoluble
X	soluble	soluble
Y	soluble	insoluble
Z	soluble	insoluble

More tests were carried out on solutions **W**, **X**, **Y** and **Z**. For each of the four solutions, about 1 cm^3 of the solution was poured into a test tube and then some dilute nitric acid and successively a few drops of silver nitrate solution were added. The outcome in each case is given in the table below.

Solution	**+ HNO_3 (aq) and then + $AgNO_3$ (aq)**	**Further test: + NH_3 (aq) onto precipitate**
W	yellow precipitate	precipitate not even soluble in conc. NH_3 (aq)
X	cream precipitate	precipitate soluble in conc. NH_3 (aq)
Y	no visible reaction	-
Z	white precipitate	precipitate dissolves in dilute NH_3 (aq)

A further test was done on another sample of **Y**. Some sodium hydroxide solution and a piece of aluminium foil were added to around 1 cm^3 of **Y** solution and boiled. A gas **M** was given off; it had a characteristic smell and turned a piece of moist red litmus blue.

(i) Suggest the cations present in **W**, **X**, **Y** and **Z**. (4 x 2 marks)
(ii) Suggest the anions present in **W**, **X**, **Y** and **Z**. (4 x 2 marks)
(iii) Identify gas **M**. (1 mark)

Total: 40 marks

23. (a) Give the oxidation number of manganese in each of the following chemical species: Mn^{2+}, MnO_2, MnO_4^{2-} and MnO_4^-. (7 marks)

(b) The reaction between acidified potassium permanganate solution and iron(II) sulfate solution is a redox reaction; the potassium permanganate solution was acidified by the addition of sulfuric acid. The two ionic half equations for this redox reaction are:

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

$$Fe^{2+}(aq) \longrightarrow Fe^{3+}(aq) + e^-$$

(i) For each of the two half equations, indicate the oxidation number of each element in each chemical species in the equation. (8 marks)

(ii) State the rules in terms of change in oxidation number that are applied to determine whether an element is oxidized or reduced. (2 marks)

(iii) Apply these rules and explain which element is being oxidized and reduced in the two half equations. (2 marks)

(iv) Join the two half equations to give the overall ionic redox reaction, including state symbols. (4 marks)

(v) Give the full chemical equation representing the redox reaction. (2 marks)

(vi) Indicate the colour change that takes place when $MnO_4^-(aq)$ changes to $Mn^{2+}(aq)$. (2 marks)

(vii) Indicate the colour change that takes place when $Fe^{2+}(aq)$ changes to $Fe^{3+}(aq)$. (2 marks)

(c) Consider the following three complex ions: $[Fe(H_2O)_6]^{2+}$, $[Cu(NH_3)_4]^{2+}$, $[CuCl_4]^{2-}$.

(i) Explain briefly, using an appropriate structural formula, the bonding in $[CuCl_4]^{2-}$. (4 marks)

(ii) Indicate, using appropriate diagrams, the shape of $[Fe(H_2O)_6]^{2+}$ and $[CuCl_4]^{2-}$. (4 marks)

(iii) Give the charge carried by: iron in $[Fe(H_2O)_6]^{2+}$, copper in $[Cu(NH_3)_4]^{2+}$, and iron in $[Fe(CN)_6]^{3-}$. (3 marks)

Total: 40 marks

24. The following is the introduction of the sheet given during the practical session of a GCSE class. This experiment dealt with the effect of catalysts on the rate of decomposition of hydrogen peroxide.

"**Experiment to see how the rate of decomposition of hydrogen peroxide is affected by the addition of potential catalysts**

Hydrogen peroxide solution decomposes slowly at room temperature . . . You are to investigate the effect of a number of potential catalysts on the rate of the reaction. . . .

Apparatus and materials: spatula, measuring cylinder, stop clock, conical flask, stopper, tubing, gas syringe, hydrogen peroxide solution, a number of catalysts . . ."

(http://www.lgschemistry.org.uk/PDF/C2.4_Rate_of_Reaction_-_Catalyst.pdf)

(a) (i) Write the chemical equation, including state symbols, for the reaction taking place. (2 marks)

(ii) Explain briefly the term catalyst. (4 marks)

(iii) Suggest a potential catalyst for the decomposition of hydrogen peroxide. (1 mark)

(iv) Suggest an experimental procedure that can be carried out, using the apparatus and substances indicated, in order to carry out the "Experiment to see how the rate of decomposition of hydrogen peroxide is affected by the addition of potential catalysts". In your account, include an appropriately labeled diagram showing the apparatus used to carry out the investigation. (14 marks)

(b) (i) As the reaction proceeds, the amounts of reactant and products change. Sketch two graphs, one for the reactant and one for any of the products, showing the change in amount with time as the reaction proceeds. Indicate clearly what is plotted on each of the two axes. (6 marks)

(ii) Explain briefly what is expected to happen to the rate of the reaction if each of the following changes are carried out: the concentration of the hydrogen peroxide solution is increased; more catalyst is added to the hydrogen peroxide solution; and the decomposition reaction is carried out at a higher temperature than room temperature. (9 marks)

(c) The vast majority of reactions take place through a **reaction mechanism** involving a number of steps. On the other hand, very few chemical reactions take place in one single step, that is, one elementary step. A reaction mechanism would have its **rate-determining step**.

Explain briefly the two underlined terms in the statement. (4 marks)

Total: 40 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