Index No:_____ **IM 06.14s**

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
INTERMEDIATE LEVEL
SEPTEMBER 2014

SUBJECT:	CHEMISTRY
DATE:	6th September 2014
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, O = 16, S = 32, Fe = 56

A Periodic Table is included.

Section A
Answer all questions in this Section

1. Complete the following table *(You may refer to the Periodic Table)*:

Particle	Protons	Neutrons	Electrons
N^{3-}		7	
	12		10

(4 marks)

2. (a) Name **three** types of radiation which may be emitted by radioisotopes.

_____

(b) Which type of radiation has the least ionisation power?

_____

(c) Complete the following nuclear reaction:

$$^{14}_{6}C \longrightarrow {}^{14}_{7}N + \_\_\_\_\_$$

(5 marks)

3. Write balanced chemical equations, including state symbols, for the following reactions taking place under **aqueous** conditions:

   (a) Magnesium + Hydrochloric acid → Magnesium chloride + Hydrogen

   _____

   (b) Lead nitrate + Sodium sulfate → Lead sulfate + Sodium nitrate

   _____

   (6 marks)

4. Give the electron configuration, using the s, p, d notation, for the following atoms and ions:

   (a) $_{5}B$ _____

   (b) $_{9}F^{-}$ _____

   (c) $_{13}Al^{3+}$ _____

   (6 marks)

5. Consider the following unbalanced equation:

$$I_2 + S_2O_3^{2-} \longrightarrow I^- + S_4O_6^{2-}$$

   (a) Give the oxidation number of iodine in:

   (i) I_2 _____ (ii) I^- _____

   (b) Give the oxidation number of sulfur in:

   (i) $S_2O_3^{2-}$ _____ (ii) $S_4O_6^{2-}$ _____

   (c) Explain what is happening in the above redox reaction in terms of a change in the oxidation number of the respective elements.

   _____

   _____

   _____ (6 marks)

6. (a) Define the term **homologous series**.

_____

_____

_____

(b) To which homologous series do the following compounds belong?

(i) $CH_3CH_2CH_3$ _____

(ii) CH_2CH_2 _____

(iii) $CH_3CH_2CH_2OH$ _____ (5 marks)

7. (a) Define the term **dynamic equilibrium**.

_____

_____

_____

(b) Write a chemical equation to indicate the reaction taking place during the Haber process for the production of ammonia.

_____ (5 marks)

8. Use the following compounds to give an example of:

CH_3COOH NaOH HCl NH_3

(a) Strong acid _____

(b) Weak acid _____

(c) Strong base _____

(d) Weak base _____ (4 marks)

9. (a) Define **standard enthalpy of combustion**.

_____

_____

(b) (i) Comment on the fact that hydrogen is said to be a high-energy source, given that the enthalpy of combustion of hydrogen is -286 kJ mol^{-1} while that of octane is -5530 kJ mol^{-1}.

_____

_____

(ii) Currently, hydrogen is not being widely used as a fuel. Mention a possible cause for this delay.

_____

_____ (5 marks)

10. Fill in the blanks in the following paragraph.

Across a period of the Periodic Table there is a _____ in the atomic radius of the elements, which is accompanied, by a _____ in the first ionisation energy of the elements. Down a group of the Periodic Table there is an _____ in the atomic radius of the elements and a _____ in the first ionisation energy of the elements. (5 marks)

11. (a) Draw the shape, of the following molecules:

SF_6		NH_4^+	

(b) Indicate the types of bonds present in NH_4Cl.

_____ (7 marks)

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12. (a) Write a balanced chemical equation, including state symbols, for the reaction of chlorine with thiosulfate.

(b) Explain why the oxidation product of the reaction in part (a) is different from the oxidation product of the reaction between thiosulfate and iodine.

(5 marks)

13. Consider the following reaction:

$$N_2O_{4(g)} \overset{\text{heat}}{\rightleftharpoons} 2NO_{2(g)}$$

(a) Determine whether the forward reaction is endothermic or exothermic.

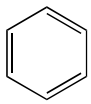
(b) What happens to the equilibrium position when the reaction temperature is increased at constant pressure?

(c) What happens to the equilibrium position when the total pressure is increased at constant temperature?

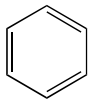
(d) Write an expression for the equilibrium constant with respect to pressure, *Kp*, and state its units in Pascals.

(6 marks)

14. Complete the following reactions by giving the structural formula of the **organic product**:



+ Cl_2 / $FeCl_3$ _____



+ *conc* HNO_3 and conc H_2SO_4 / 55^oC _____

(4 marks)

15. (a) Give the chemical formula of a transition metal compound that catalyses the decomposition of hydrogen peroxide.

_____

(b) Explain what would be **observed** if the catalyst mention in part (a) is added to a test-tube containing hydrogen peroxide.

_____

(c) Why is there a change in the rate of reaction when the catalyst is added to hydrogen peroxide solution?

_____

_____

_____

(d) Name the property that enables transition metals and their compounds to act as catalysts.

_____ (7 marks)

Section B

Answer all questions in this Section

16. (a) Give the definition of a covalent bond.

_____

_____

_____

_____ (4 marks)

(b) (i) Explain the term *ligand*?

_____

_____

(ii) Give **two** examples of such ligands?

_____

_____ (5 marks)

(c) Give an example of (i) an octahedral complex ion and (ii) a linear complex, indicating the oxidation number of the metal ion in the complex.

(i) _____ (ii) _____

Oxidation number _____ Oxidation number _____

(6 marks)

(d) What type of bonding is present between the ligands and the metal ion?

_____ (1 mark)

Total: 16 marks

17. (a) Define **standard enthalpy of formation.**

_____

_____ (2 marks)

(b) The table below gives the standard enthalpies of combustion for the following compounds:

Compound	$\Delta H^{o}_{combustion}$ (kJ mol^{-1})
$C_{(s)}$	-394
$H_{2\,(g)}$	-286
$C_6H_{6\,(l)}$	-3276

(i) Draw a Hess' cycle that can be used to calculate the standard enthalpy of formation of benzene, C_6H_6, from the standard enthalpies of combustion given in part (b).

(ii) Calculate the standard enthalpy of formation of benzene.

_____

_____

_____

_____ (11 marks)

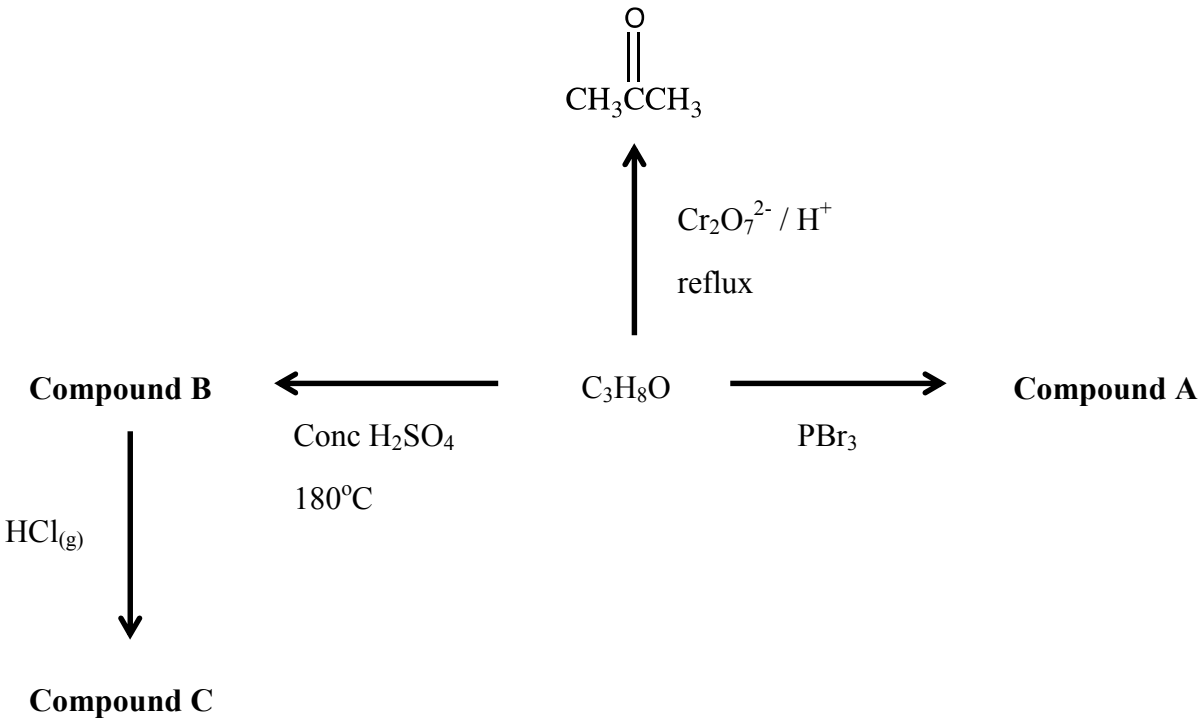
(c) Is the formation of benzene endothermic or exothermic? Explain.

_____

_____ (3 marks)

Total: 16 marks

18. Consider the following scheme:



(a) (i) Give the structural formula for the compound with the molecular formula C_3H_8O.

_____

(ii) Give the systematic name of the compound with the formula CH_3COCH_3.

_____ (4 marks)

(b) Give the structural formulae for compounds A, B and C.

A: _____ B: _____ C: _____ (9 marks)

(c) Give the structural formula of the ether that forms when excess C_3H_8O is reacted with concentrated sulfuric aid at 140°C.

_____ (3 marks)

Total: 16 marks

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19. (a) An aqueous solution of 0.1 mol dm^{-3} ethylamine, $CH_3CH_2NH_2$, was found to have a pH of 11.8.

(i) Give a chemical equation for the acid-base reaction between a solution of ethylamine and hydrochloric acid.

(ii) Identify the conjugate acid-base pairs in the equation given in part (a)(i).

Acid: _____ Base: _____

Conjugate base: _____ Conjugate acid: _____

(7 marks)

(b) Given that the ionic product of water, K_w, is 1 x 10^{-14} mol^2 dm^{-6}, calculate the concentration of OH^- ions present in 0.1mol dm^{-3} ethylamine.

(6 marks)

(c) What happens to the pH and to the concentration of H^+ ions of a solution of ethylamine upon addition of a small amount of dilute hydrochloric acid?

(3 marks)

Total: 16 marks

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20. (a) A mixture was given to a group of students. Devise a procedure that can be carried out in the laboratory in order to separate a mixture of sand, salt (sodium chloride) and water into its pure individual components. Accompany the description by a fully labelled diagram of the apparatus used.

(14 marks)

(b) What test can be carried out to confirm that the procedure given in part (a) produced pure water?

(2 marks)

Total: 16 marks

Section C

Answer TWO questions from this Section

Write your answers on the lined pages provided.

21. (a) Iron(II) sulfate can be oxidised using acidified potassium permanganate solution. The two half equations that represent this redox reaction are:

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

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

A redox titration was carried out in order to find the concentration of an iron(II) sulfate solution using a 0.05 mol dm^{-3} potassium permanganate solution.

The following procedure was followed:

1) By using a pipette (fitted with pipette filler), a 25 mL sample of the Fe^{2+} solution was poured into a 250 mL conical flask.
2) Then, 50 mL of distilled water and 15 mL of 5.0 mol dm^{-3} sulfuric acid solution were added into the flask.
3) The burette was filled with the $KMnO_4$ solution, and the initial burette reading was recorded.
4) The sample was titrated with the $KMnO_4$ solution to a faint pink end-point and the final burette reading was recorded.
5) The titration was repeated a number of times using a new sample of the Fe(II) solution until a number of concordant titre values were obtained.

The following readings were recorded:

	Titration 1	**Titration 2**	**Titration 3**	**Titration 4**
Final burette reading (mL)	20.90	40.95	20.00	39.95
Initial burette reading (mL)	0.00	20.90	0.00	20.00

(i) Considering the two half equations, give the overall balanced equation for the redox reaction that is taking place. (3 marks)

(ii) The oxidation and reduction half equations do not include the **spectator ions**. Explain briefly what the term 'spectator ions' means, and indicate the 'spectator ions' in this reaction. (5 marks)

(iii) The reduction half equation includes "$8H^+(aq)$". What is the source of the "$8H^+(aq)$"? (2 marks)

(iv) Explain the term "concordant titre values". (2 marks)

(v) Find the concentration of the iron(II) sulfate solution. (10 marks)

(vi) Find the mass of iron(II) sulfate-6-water that must be dissolved in 250 mL of distilled water in order to prepare a solution of the concentation found in part (v). (8 marks)

The question continues on the next page

(b) A mass of 1.73 g of a very volatile liquid was placed in a closed container and heated to a temperature of 27°C. All the liquid was vaporised at this temperature. The pressure of the gas was 150,000 Pa and it occupied a volume of 0.90 dm^3. Find the relative atomic mass of the liquid. (10 marks)

Total: 40 marks

22. (a) Alkanes, alkenes and alkynes are three homologous series that are classified as **aliphatic hydrocarbons**.

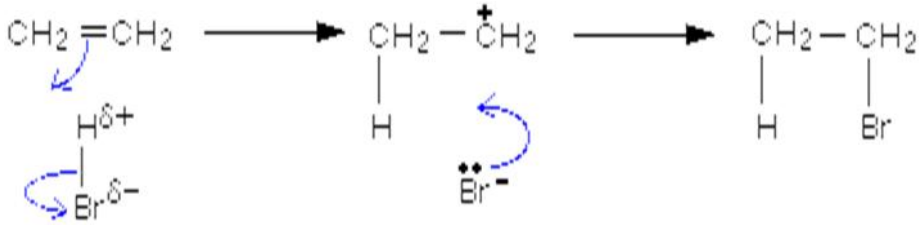
(i) Explain briefly each of the following two terms: **aliphatic** and **hydrocarbons**. (4 marks)

(ii) The typical reactions of alkanes are substitution reactions while those for alkynes are addition reactions. Explain briefly, illustrating your answer with suitable examples. (10 marks)

(iii) Methane reacts with chlorine, adopting a **free radical mechanism**. Explain briefly the **three** steps of this mechanism supporting your answer with relevant equations. Show mechanistic equations for the formation of the monochlorinated product. (11 marks)

(iv) Propene reacts with hydrogen chloride to give a halogenoalkane following Markovnikov's rule. Explain briefly. (5 marks)

(b) Ethene and hydrogen bromide react together according to the following proposed reaction mechanism, which has two steps:



Indicate the rate-determining step, giving reasons for your answer. (4 marks)

(c) Consider the exothermic reaction: A + B → X.

(i) Draw a reaction profile that represents this reaction, indicating clearly the activation energy. (4 marks)

(ii) Using the same set of axes for part (c)(i), draw the profile for the same reaction when a suitable catalyst is used. (2 marks)

Total: 40 marks

23. Consider the following tests carried out on substances **A**, **D** and **E**. Indicate the inference/conclusion that can be deduced from each test and hence identify each substance. **Give chemical or ionic equations wherever reactions take place**.

(a) The following tests were carried out on substance **A**:
- On adding some drops of sulfuric acid to around 2 cm^3 of a solution of substance **A**, a white precipitate was produced.
- To another 2 cm^3 of a solution of substance **A**, a few drops of dilute nitric acid followed by a few drops of silver nitrate solution were added. A yellow precipitate was formed, which resulted to be insoluble in concentrated ammonia solution.
- A flame test of substance **A** produced an apple green colour. (14 marks)

(b) The following tests were carried out on substance **D**:
- A white solid substance **D** gave a golden yellow colour when placed in a Bunsen burner flame.
- It dissolved in water, and gave bubbles of a colourless, odourless gas when dilute hydrochloric acid was added to the solution. Bubbles of gas were also given off when dilute hydrochloric acid was added to the solid. The gas evolved was bubbled through lime water solution and turned it milky. (9 marks)

(c) Substance **E** is a coloured salt. The following tests were carried out on substance **E**:
- On adding sodium hydroxide solution to a solution of **E**, a blue precipitate formed, found to be insoluble on addition of excess sodium hydroxide solution.
- On adding ammonia solution to a solution of **E**, a blue precipitate formed, which dissolved on addition of excess ammonia solution giving a deep blue solution.
- On adding dilute hydrochloric acid followed by a few drops of barium chloride solution to a clear solution of **E**, a white precipitate formed.
- On heating strongly a sample of the crystalline solid **E**, a white powder was produced, which regained its colour on addition of a few drops of water. (17 marks)

Total: 40 marks

24. Consider the following statements:

(a) Sodium and chlorine bond to form sodium chloride. Sodium chloride has a **lattice structure**. Explain the term in bold, including a diagram in your answer. (10 marks)

(b) Hydrogen, oxygen and nitrogen molecules are all **covalently bonded**, but they present a *different* bonding situation. Justify this statement and explain the term in bold. (8 marks)

(c) Carbon dioxide molecules are **non-polar**. On the other hand, hydrogen chloride and water molecules are **polar**. Explain this statement by discussing the shapes of these molecules. (12 marks)

(d) Phosphorus forms two chlorides: **PCl_3** and **PCl_5**. In the former case there is a total of eight external electrons upon bonding, while in the case of PCl_5 there is 'octet expansion'. Explain this statement and say how this is possible. (10 marks)

Total: 40 marks

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PERIODIC TABLE

I	II											III	IV	V	VI	VII	VIII
							Key										
1 **H** 1							*Relative atomic mass* — A X Z — *Atomic Number*										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