Index Number:_____ IM06.20s

L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

INTERMEDIATE MATRICULATION LEVEL
2020 SECOND SESSION

SUBJECT:	**Chemistry**
DATE:	12th December 2020
TIME:	4:00 p.m. to 7:05 p.m.

Useful information

Ideal gas constant = 8.31 $JK^{-1}mol^{-1}$
Relative atomic masses: H = 1, C = 12, O = 16, Na = 23, S = 32
A Periodic Table is included.

SECTION A

Answer ALL questions in this section.

1. Propene reacts with hydrogen bromide to give a bromo-substituted alkane.
   (a) Write a balanced equation for the reaction of propene with hydrogen bromide.

_____ (1)

   (b) Give the balanced equation for the reaction of propene with hydrogen bromide in terms of structural formulae.

(1)

   (c) What is the type of reaction between propene and hydrogen bromide called?

_____ (½)

   (d) Name the rule that is followed in the reaction between propene and hydrogen bromide.

_____ (½)

(Total: 3 marks)

Please turn the page.

2. (a) Give the electronic configuration, in spdf notation, of:

Na: _____ (½)

Cl: _____ (½)

(b) Sodium and chlorine react to form sodium chloride. Draw the dot-and-cross diagrams that represent the sodium ion and the chloride ion.

(2)
(Total: 3 marks)

3. Hydrogen gas and chlorine gas react to give hydrogen chloride gas. A mixture made up of 30 cm^3 of hydrogen gas and 50 cm^3 of chlorine gas undergo reaction to give hydrogen chloride gas. All gaseous volumes are measured at the same temperature and pressure.

(a) Write a balanced equation, including state symbols, for the reaction between hydrogen gas and chlorine gas.

_____ (½)

(b) Assuming that all the hydrogen gas has reacted, showing all the necessary working, calculate:

(i) the volume of chlorine gas that reacted;

_____

_____ (½)

(ii) the volume of the reactant gas in excess after reaction, if any. Indicate also the name of the reactant gas in excess, if any;

_____

_____ (1)

(iii) the volume of hydrogen chloride gas produced;

_____

_____ (1)

(iv) the total volume of gas after reaction.

_____

_____ (1)
(Total: 4 marks)

4. (a) Two reagent bottles contain 0.01 moldm^{-3} solutions of hydrochloric acid and sulfuric acid. Calculate the pH of the hydrochloric acid and sulfuric acid solutions.

_____

_____

_____

_____ (3)

(b) Which is the stronger acid between hydrochloric acid and sulfuric acid? Explain your answer.

_____

_____ (1)

(Total: 4 marks)

5. (a) Most reactions take place through a reaction mechanism. The reaction mechanism has a rate determining step. Explain the following terms:

(i) reaction mechanism: _____

_____

_____ (1)

(ii) rate determining step: _____

_____

_____ (1)

(b) Draw the energy profile of an exothermic reaction and indicate the activation energy on the graph.

(2)

(Total: 4 marks)

6. There are periodic relationships among elements, and physical properties vary with atomic number. Considering the elements Li to Ne, explain how **each** of the following properties varies:

(a) the valency: _____

_____

_____

_____ (1)

(b) the atomic radius: _____

_____

_____

_____ (1)

(c) the first ionisation energy: _____

_____

_____

_____ (2)

(Total: 4 marks)

7. A sample of carbon dioxide gas occupies a volume of 0.02 m^3 at a pressure of 101,325 Pa and a temperature of 17 ^oC.

(a) Find the number of moles of gas present.

_____

_____

_____

_____ (2½)

(b) Find the mass of the gas sample.

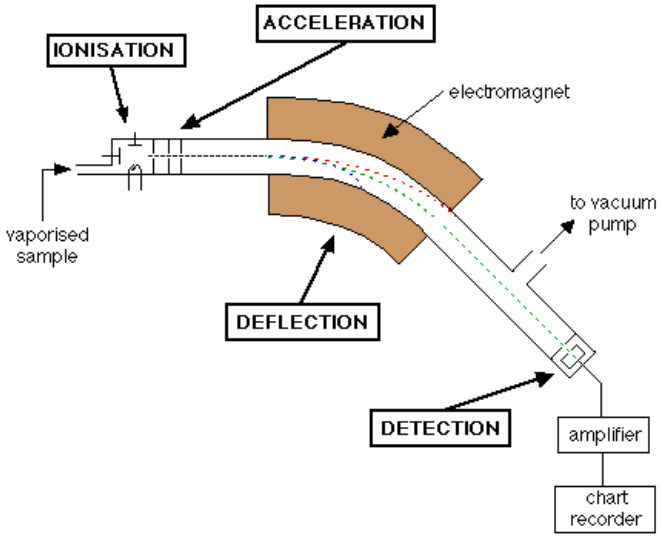
_____

_____

_____ (1½)

(Total: 4 marks)

8. The following is a schematic diagram of a mass spectrometer.



https://www.chemguide.co.uk/analysis/masspec/howitworks.html

(a) In the ionisation chamber, the atom or molecule of the sample is ionised. Explain.

_____

_____

_____ (1)

(b) The ions produced are accelerated and then deflected. The ions travel through vacuum. Explain.

_____

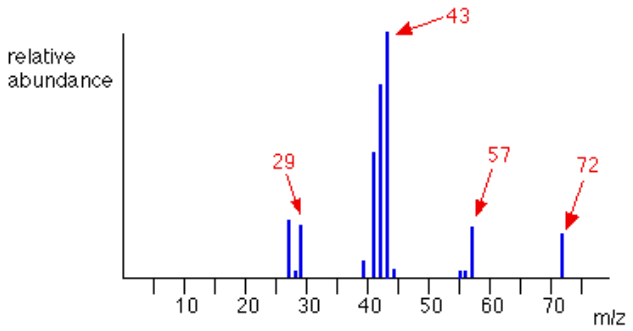
_____

_____

_____ (1½)

(c) Consider the following (simplified) mass spectrum for pentane. Considering that the peak at m/z = 72 is the molecular ion, deduce the fragments at:

simplified mass spectrum of pentane - $CH_3CH_2CH_2CH_2CH_3$



(i) m/z = 57: _____

(ii) m/z = 43: _____

(iii) m/z = 29: _____

(1½)

https://www.chemguide.co.uk/analysis/masspec/fragment.html#top

(Total: 4 marks)

SECTION B

Answer ALL questions in this section.

9. Chlorine reacts with water to give hydrochloric acid and chloric(I) acid. This is a disproportionation reaction.

$$Cl_2\ (g) + H_2O\ (l) \longrightarrow HCl\ (aq) + HClO\ (aq)$$

(a) What is a disproportionation reaction?

_____

_____

_____(1)

(b) Using oxidation numbers, show how the above reaction is a disproportionation reaction.

_____

_____

_____

_____

_____

_____ (3)

(c) Zinc solid reacts with copper sulfate solution to give zinc sulfate solution and copper metal.

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

(i) Identify the oxidising agent and the reducing agent in this redox reaction.

Oxidising agent: _____

Reducing agent: _____ (1)

(ii) Explain this reaction in terms of the electrochemical series.

_____

_____

_____(1)

(Total: 6 marks)

10. In the Haber process, nitrogen from the air combines with hydrogen, derived mainly from natural gas (methane), to produce ammonia. It is a reversible reaction. The chemical equation for the reaction, and the corresponding ΔH value, is:

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g) \qquad \Delta H = -91.8\ kJmol^{-1}$$

A catalyst is used for the reaction. The pressure varies from one manufacturing plant to another, but is always high; it is usually quoted at 200 atmospheres. The temperature is 400 to 450 ^{o}C.

(a) State Le Chatelier's principle.

_____

_____

_____

_____(2)

(b) If the above process is carried out at a pressure of 100 atmospheres, the yield of ammonia changes. Explain in terms of Le Chatelier's principle.

_____

_____

_____ (1½)

(c) (i) If the above process is carried out at a temperature of 200 ^{o}C, the yield of ammonia changes. Explain in terms of Le Chatelier's principle.

_____

_____

_____ (1½)

(ii) Considering your answer to part (c)(i), why is the actual imposed temperature 400 to 450 ^{o}C?

_____

_____

_____(1)

(Total: 6 marks)

11. Draw the shape, including lone pairs where present, and give the name of the shape, of the following molecules:

(a) CH_4

(2)

(b) NH_3

(2)

(c) H_2O

(2)

(Total: 6 marks)

12. (a) There are two isomers with the formula C_3H_6. Explain.

_____

_____

_____

_____(2)

(b) Substitution reactions of alkanes with halogens take place through a free radical mechanism. Explain by showing the mechanism of the reaction.

_____

_____

_____

_____

_____

_____(4)

(Total: 6 marks)

13. (a) Three solutions labelled A, B and C contain chloride, bromide and iodide ions. Give simple chemical tests to distinguish between the three.

_____

_____

_____

_____(2)

(b) Two solutions labelled X and Y contain nitrate(III) and nitrate(V) ions. Give simple chemical tests to distinguish between the two.

_____

_____

_____

_____(2)

(c) Two solutions labelled D and E contain sulfate(IV) and sulfate(VI) ions. Give simple chemical tests to distinguish between the two.

_____

_____

_____

_____(2)

(Total: 6 marks)

SECTION C

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

14. This question is about transition metals.
    (a) Transition metals are characterised by having coloured compounds and variable oxidation states. Write the oxidation state of manganese in the following species and write the colour of each: Mn^{2+}, MnO_2, MnO_4^{2-}, MnO_4^-. (2)
    (b) (i) One of the above manganese species is a catalyst in the decomposition of hydrogen peroxide. Identify the catalyst. (1)
    (ii) Write a fully balanced equation, including state symbols, for the decomposition of hydrogen peroxide. (2)
    (iii) This reaction can be used as an experiment in kinetics to investigate the rate of a reaction. How does a catalyst in a reaction function, and what changes (if any) are expected in the rate of the reaction if the amount of the catalyst added to the reaction is increased? (3)
    (c) (i) You are provided with two solutions which look quite similar. One solution contains a magnesium soluble salt and the other has a manganese soluble salt. Describe how to chemically distinguish between these two solutions. (3)
    (ii) Write a fully balanced ionic equation, including state symbols, for one of the above reactions. (2)
    (d) Transition metals form complex ions.
    (i) Give the formula of a complex ion of iron. (1)
    (ii) Draw the structure of the complex ion in part d(i), and name its shape. (2)
    (iii) Explain the bonding in the complex and identify the ligand in the complex. (4)

(Total: 20 marks)

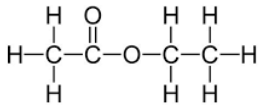
15. This question is about thermochemistry.
    (a) (i) Define the standard enthalpy of formation of a compound. (1)
    (ii) Write a fully balanced equation, including state symbols, for the formation of liquid carbon disulfide CS_2 from its elements in their standard states. (2)
    (iii) Carbon disulfide burns in air to form carbon dioxide and sulfur dioxide. Write a fully balanced equation, including state symbols, for the combustion of carbon disulfide. (2)
    (iv) The standard enthalpies of combustion for carbon disulfide, sulfur and carbon are -1075 $kJmol^{-1}$, -298 $kJmol^{-1}$, and -394 $kJmol^{-1}$ respectively. Draw Hess's cycle to show how the standard enthalpy of formation of carbon disulphide can be calculated from these values of standard heats of combustion. (3)
    (v) Calculate the standard enthalpy of formation of carbon disulphide CS_2. (3)
    (b) (i) Define bond dissociation enthalpy. (1)
    (ii) The standard bond dissociation enthalpies for the first, second and third N-H bonds in ammonia are 453, 381 and 360 $kJmol^{-1}$ respectively. Calculate the average bond dissociation energy for the N-H bond. (2)
    (iii) The bond enthalpy terms for the H-H bond and the N≡N bond are 436 and 941 $kJmol^{-1}$ respectively. Use these values and your answer in part (b)(ii) to calculate the enthalpy change for the following complete reaction: $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$ (3)
    (iv) Two different terms – bond dissociation enthalpy and bond enthalpy terms – are used in this question. Discuss the difference between these terms. (1)
    (v) Use the value obtained in part (b)(iii) to calculate the enthalpy of formation of ammonia. (2)

(Total: 20 marks)

16. Sodium thiosulfate ($Na_2S_2O_3$) is often used for the titrimetric analysis of iodine. In the process the thiosulfate ion ($S_2O_3^{2-}$) is changed to the tetrathionate ion ($S_4O_6^{2-}$) by iodine. This is a redox reaction.
    (a) (i) Define redox reaction. (1)
    (ii) Identify the reducing agent in the reaction between iodine and sodium thiosulfate. (1)
    (b) Write balanced equations for:
    (i) the oxidation of the thiosulfate ion to the tetrathionate ion (half ionic equation);
    (ii) the reduction of iodine (half ionic equation); and
    (iii) the redox reaction between thiosulfate and iodine (full equation). (3)
    (c) In a lab experiment, iodine is used to find the percentage purity of a sample of solid sodium thiosulfate $Na_2S_2O_3.5H_2O$. In the first step, 0.30 g of hydrated sodium thiosulfate was added to 25.00 cm^3 of 0.05 $moldm^{-3}$ iodine solution. In a second step, the excess of iodine which did not react and remained after the first reaction needed 28.00 cm^3 of 0.04 $moldm^{-3}$ of sodium thiosulfate in a titration.
    (i) Calculate the number of moles of thiosulfate which reacted in the second step with the excess iodine from the first reaction. (1)
    (ii) Calculate the number of moles of iodine which reacted with the thiosulfate in the first step. (4)
    (iii) Calculate the number of moles of thiosulfate which reacted in the first step. (2)
    (iv) Calculate the mass of the hydrated sodium thiosulfate which was present in the sample. (2)
    (v) Calculate the percentage purity of the sample. (2)
    (d) Both chlorine and iodine are elements in Group 7 of the Periodic Table. Chlorine oxidises the thiosulfate ion to the sulfate ion (SO_4^{2-}).
    (i) Find the oxidation numbers of S in SO_4^{2-}, SO_3^{2-}, $S_2O_3^{2-}$, $S_4O_6^{2-}$. (2)
    (ii) Explain why chlorine and iodine produce different products when each reacts with sodium thiosulfate. (2)

(Total: 20 marks)

17. This question is about organic chemistry.
    (a) A compound M is a three-carbon organic compound which is isomeric with compound N. Both compound M and compound N reacted with excess concentrated sulfuric acid at 180°C to produce the hydrocarbon O. M reacted with a limited amount of acidified potassium dichromate to form compound P which did not react with Fehling solution. N reacted with a limited amount of acidified potassium dichromate to form compound Q. Compound Q reacted with Fehling's solution.
    (i) Draw the structures of M, N, O, P and Q. (2½)
    (ii) Name compounds M, N, O, P, and Q. (2½)
    (b) A carboxylic acid R reacts with an alcohol S to form the following compound T.



    (i) Name the carboxylic acid R. (1)
    (ii) Draw the structure of the alcohol S. (1)
    (iii) Name the class of compounds of compound T. (1)
    (iv) Explain how compound T can be prepared starting from the organic compound S only. Name the reagents and conditions for each step. (Assume that common lab reagents such as acids, oxidising and reducing agents are available.) (5)
    (c) Both methylamine and ammonia have basic properties.
    (i) Explain the following statement: methylamine is a primary amine and it is a stronger base than ammonia. (2)
    (ii) Write an equation for a reaction which shows the basic nature of methylamine. (1)
    (iii) Phenylamine is another primary amine. Explain how phenylamine can be prepared, starting from benzene. (4)

(Total: 20 marks)

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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															

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