

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD  
UNIVERSITY OF MALTA, MSIDA  
MATRICULATION EXAMINATION  
INTERMEDIATE LEVEL  
SEPTEMBER 2017

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<b>SUBJECT:</b>	CHEMISTRY
<b>DATE:</b>	31 <sup>st</sup> August 2017
<b>TIME:</b>	4:00 p.m. to 7:05 p.m.

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**Useful information**

Relative atomic masses: C = 12, O = 16

Avogadro's Number =  $6 \times 10^{23}$ 

A Periodic Table is included.

**SECTION A****Answer ALL questions in this section.**

1. There are alpha and beta particles, and gamma radiation.
- (a) Write the symbols, including mass number and atomic number, of an alpha and a beta particle.
- (i) Alpha particle: \_\_\_\_\_ (1)
- (ii) Beta particle: \_\_\_\_\_ (1)
- (b) "A radioisotope used for diagnosis must emit gamma rays of sufficient energy to escape from the body and it must have a half-life short enough for it to decay away soon after imaging is completed. The radioisotope most widely used in medicine is technetium-99m, employed in some 80% of all nuclear medicine procedures."

[https://www.radiochemistry.org/nuclearmedicine/radioisotopes/01\\_isotopes.shtml](https://www.radiochemistry.org/nuclearmedicine/radioisotopes/01_isotopes.shtml)

Define the term half-life.

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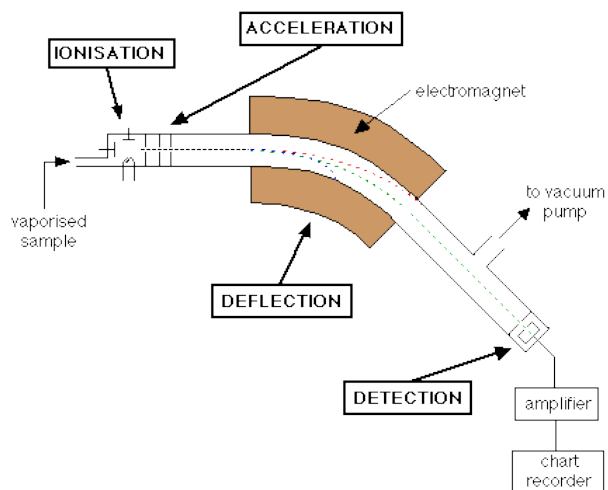
(1)

**(Total: 3 marks)**

2. Draw dot-and-cross diagrams of the following three molecules: (a) oxygen; (b) aluminium chloride; and (c) phosphorus pentachloride.

**(Total: 3 marks)**

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



[www.chemguide.co.uk/analysis/masspec/howitworks.html](http://www.chemguide.co.uk/analysis/masspec/howitworks.html)

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(a) Explain what happens (and how it happens) in the region labelled:

(i) ionisation: \_\_\_\_\_

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(1)

(ii) acceleration: \_\_\_\_\_

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(1)

(iii) deflection: \_\_\_\_\_

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(1)

(b) Molecules can fragment in the mass spectrometer. Explain.

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(1)

**(Total: 4 marks)**

4. Sodium and potassium are both Group I elements, and so both have one valence electron.

(a) Explain why, although sodium and potassium are both Group I elements, they have a different first ionisation energy.

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(2)

(b) Explain the term valence electron.

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(1)

*This question continues on the next page.*

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(c) Explain the term electron affinity.

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(1)

**(Total: 4 marks)**

5. In the Haber process, nitrogen and hydrogen are in equilibrium with ammonia. All chemical species involved are gaseous.

(a) Write a balanced equation, including state symbols, of the equilibrium reaction between nitrogen and hydrogen.

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(1)

(b) After equilibrium has been reached, explain what happens when the following takes place:

(i) an increase in the amount of hydrogen in the equilibrium mixture;

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(1)

(ii) an increase in pressure;

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(1)

(iii) an increase in temperature, considering that the enthalpy change of the forward reaction is  $-92 \text{ kJ/mol}$ .

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(1)

**(Total: 4 marks)**

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6. There are acids, bases, alkalis and salts. Acids and bases can be strong or weak.  
(a) Distinguish between a base and an alkali.

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(1)

- (b) Distinguish between strong and weak acids and bases.

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(1)

- (c) There are amphoteric compounds. Explain briefly, illustrating your answer with a suitable example.

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(2)

**(Total: 4 marks)**

7. Going through period 2 – from lithium to neon – and period 3 – from sodium to argon – one notices periodicity in the properties of the elements and their compounds.  
(a) Explain the term periodicity.

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(1)

- (b) Show how periodicity is shown in:  
(i) trends in the melting points of the oxides;

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(1)

- (ii) the reaction of the oxides with water.

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(2)

**(Total: 4 marks)**

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8. (a) Typically, alkanes undergo substitution reactions while alkenes undergo addition reactions. Considering ethane and ethene, give an example of each type of reaction.

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(2)

- (b) Consider the addition reaction of propene with hydrogen chloride. There are two possible products, but one product is dominant. Explain, including relevant chemical equations.

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(2)

**(Total: 4 marks)**

## SECTION B

Answer ALL questions in this section.

9. Consider the following gaseous reaction:  $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \longrightarrow 2\text{HCl}(\text{g})$
- (a) Assume that the initial mixture is composed of  $40 \text{ cm}^3$  of hydrogen gas and  $10 \text{ cm}^3$  of chlorine gas, and that the reaction goes to completion. Showing all necessary calculations, find:
- (i) the volume of hydrogen chloride gas produced;

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(1)

- (ii) the volume of any excess reactant gas after reaction;

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(1)

- (iii) the difference in the total volume of gas between before and after reaction.

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(2)

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- (b) Mention and state the law that is assumed in carrying out these calculations. Indicate the assumption that is being adopted.

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\_\_\_\_\_ (2)  
**(Total: 6 marks)**

10. A sample of carbon dioxide gas occupying a volume of  $100,000 \text{ cm}^3$  and at a pressure of  $100,000 \text{ Pa}$ , is kept at a temperature of  $327 \text{ }^\circ\text{C}$ .

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

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\_\_\_\_\_ (3)

- (b) Find the mass of gas present.

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\_\_\_\_\_ (2)

- (c) Describe a simple chemical test that shows the presence of carbon dioxide.

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\_\_\_\_\_ (1)  
**(Total: 6 marks)**

*Please turn the page.*

11. Explain the following statements:

- (a) There is covalent bonding in both the hydrogen and the hydrogen chloride molecules. Both molecules are diatomic, but one is polar while the other is non-polar.

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- (b) Cyclohexane and benzene are both six-membered rings. There is delocalisation of electrons (and resonance) in benzene, which is not present in cyclohexane.

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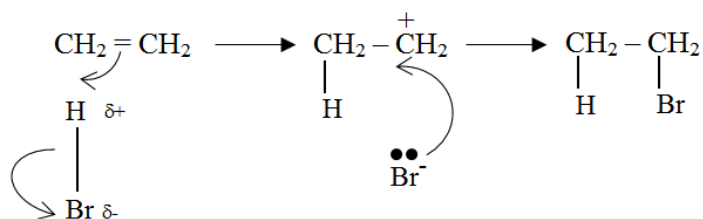
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(Total: 6 marks)

12. (a) The following scheme shows the mechanism of the reaction between ethene and hydrogen bromide.



- (i) Write the equations for the **TWO** individual steps of the mechanism indicated above.

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(ii) One of the two steps is the rate determining step. Explain briefly the meaning of the term rate determining step, and indicate and explain why this is so.

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\_\_\_\_\_ (2)

(b) (i) On the same pair of axes, draw the curve representing the distribution of molecular energies of a gas at two different temperatures.

(ii) Considering the activation energy, explain why the reaction rate increases at the higher temperature.

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\_\_\_\_\_ (3)

**(Total: 6 marks)**

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13. This question is about qualitative analysis.

- (a) There are samples of sodium, potassium, calcium and barium salts. Indicate the colours obtained when a flame test is carried out on each sample.

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(2)

- (b) Solutions of the chlorides of each of the four elements above are available. One can distinguish between the Group I and the Group II chlorides by adding sulfuric acid solution. Explain, including chemical equations where necessary.

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(2)

- (c) Describe a simple test to distinguish between solutions of sodium sulfate (IV) and sodium sulfate (VI).

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(2)

(Total: 6 marks)

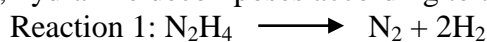
### SECTION C

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

14. This question is about chemical energetics.

Hydrazine ( $\text{N}_2\text{H}_4$  or  $\text{H}_2\text{NNH}_2$ ) is a highly toxic colourless flammable liquid which may be used in various rocket fuel mixtures. One molecule of hydrazine has a single bond between two nitrogen atoms.

- (a) In the fuel mixture, hydrazine decomposes according to the following equation:



- (i) Draw the molecular structure of hydrazine. (1)

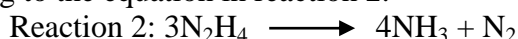
- (ii) The values of the bond dissociation enthalpies of N-H in  $\text{N}_2\text{H}_4$  and of the bond energy term of N-H in  $\text{N}_2\text{H}_4$  are not equal. Explain this statement by defining both terms and by referring to  $\text{N}_2\text{H}_4$  as an example. (4)
- (iii) Table 1 gives the bond energy terms for some bonds.

Table 1

Bond	Bond Energy Term in $\text{kJmol}^{-1}$
N-N	163
$\text{N}\equiv\text{N}$	944
N-H	388
H-H	436

Use the values in Table 1 to calculate the enthalpy change for reaction 1. (4)

- (b) In the fuel mixture, the hydrazine molecule may also decompose into ammonia and nitrogen according to the equation in reaction 2.

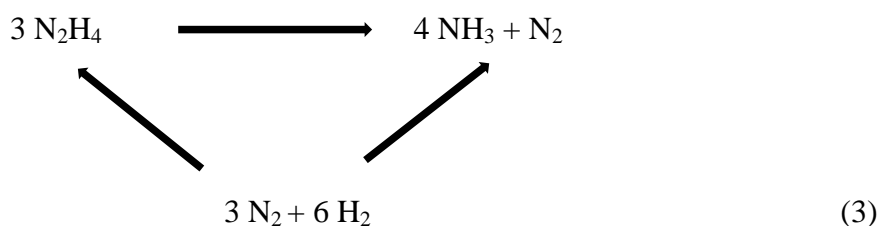


- (i) Define standard enthalpy of formation. (2)
- (ii) Give an equation which represents the standard enthalpy of formation of hydrazine. (1)
- (iii) Table 2 gives the standard enthalpy of formation for hydrazine and ammonia.

Table 2

Bond	$\Delta H_f^\circ$ in $\text{kJmol}^{-1}$
$\text{N}_2\text{H}_4$	+96
$\text{NH}_3$	-46.1

Using the following Hess's cycle and the values in Table 2, calculate the enthalpy change in reaction 2.



- (c) In the fuel mixture, ammonia and hydrazine may react to form nitrogen and hydrogen as in the equation for reaction 3.



- (i) Calculate the enthalpy change of reaction 3. (You may either use data given in Table 1 or data given in Table 2.) (4)
- (ii) Use your answer in part (c)(i) to explain why this reaction produces a decrease in the temperature of the reacting mixture if all the three reactions occur. (1)

**(Total: 20 marks)**

15. This question concerns the topic of ionic equilibria, acids and bases.
- (a) (i) Explain the term conjugate acid – base pair. (2)
- (ii) Identify the conjugate acid – base pairs in the following equation (reaction 4) relating to ethanoic acid. Reaction 4:
- $$\text{CH}_3\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}_3\text{O}^+ \quad (2)$$
- (iii) Referring to reaction 4 above, explain why a weak acid has a strong conjugate base. (2)
- (b) The pH value of  $0.01 \text{ mol dm}^{-3}$  ethanoic acid can be measured with universal indicator.
- (i) Name an instrument which gives a more accurate reading of pH than the universal indicator. (1)
- (ii) Which one of the following values of pH is most likely to be the pH value of  $0.01 \text{ mol dm}^{-3}$  ethanoic acid: pH = 2, pH = 3, pH = 7, pH = 8. Explain. (2)
- (c) Codeine ( $\text{C}_{18}\text{H}_{21}\text{NO}_3$ ) is a weak base used to treat mild to moderate pain and relieve coughing. A solution of codeine has a hydroxide concentration of  $8.912 \times 10^{-5} \text{ mol dm}^{-3}$ .
- (i) What is the pH of the codeine solution? (3)
- (ii) Using B to symbolise the base codeine, write the ionisation equation for the base. (2)
- (iii) The value of the base dissociation constant  $K_b$  for codeine is  $1.6 \times 10^{-6}$ . Using B to symbolise the base codeine, write the expression for  $K_b$  and write its units. (2)
- (iv) Under which condition/s does the value of  $K_b$  change? (1)
- (v) How does the value of  $K_b$  of weak bases relate to the strength of a base? (1)
- (vi) The values of  $K_b$  of four bases are given in Table 3 below. Write the bases in order of decreasing basic strength.

Table 3

Base	$K_b$
Codeine	$1.6 \times 10^{-6}$
ethylamine	$5.6 \times 10^{-4}$
ammonia	$1.8 \times 10^{-5}$
caffeine	$4.1 \times 10^{-4}$

(2)

**(Total: 20 marks)**

16. This question concerns the chemistry of Group VII elements.
- Explain each of the following statements. In your answer, include the name of the type of reaction taking place, experimental and observation details, balanced equations and the colour of compounds as appropriate.
- (a) Chemical tests are used to distinguish between potassium chloride and potassium bromide. (4)
- (b) Chlorine and iodine are in the same group of the Periodic Table and yet react differently with in aqueous sodium thiosulfate. (4)
- (c) A change in colour is observed when liquid bromine is added to a solution of potassium iodide but not when it is added to a solution of sodium chloride. (4)
- (d) Sulfuric (VI) acid and sodium chloride can be used to prepare hydrochloric acid, but sulfuric (VI) acid and sodium bromide are not used in the preparation of hydrogen bromide. (4)
- (e) Aqueous solutions of the hydrogen halides are acidic but some halides are more acidic than others. (4)

**(Total: 20 marks)**

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17. This question concerns organic chemistry.
- (a) Two organic liquids P and Q react to form compound R which has a fruity odour. Compound P can be prepared by reducing propanal and Q can be formed in a refluxed reaction from ethanol.
- In other reactions, depending on the conditions, P is dehydrated to either a reactive compound S or partially dehydrated to a much less reactive compound T. Compound S can be converted to a polymer U.
- (i) Identify and write the name of compounds P, Q, R and U. (2)
- (ii) Write the name of the reagents and the conditions which are required for each of the following reactions:
- P reacting with Q;
  - Preparation of P from propanal;
  - Preparation of Q from ethanol;
  - S formed as a product from P;
  - T formed as a product from P. (5)
- (iii) Write balanced equations which show the formation of R and the formation of T. (2)
- (iv) Write an equation showing the conversion of S to U. (2)
- (b) Compound V belongs to the same class of compounds as compound P. It has the same number of carbon atoms as P, but has two similar functional groups bonded to each terminal carbon. Compound W belongs to the same class of compounds as compound Q. It has the same number of carbon atoms as Q, but has two similar functional groups in each molecule. Compounds V and W may polymerise in the presence of acids to form polymer X.
- (i) Name the type of polymerisation which occurs between compounds V and W and explain the difference between this type of polymerisation and the polymerisation which resulted in formation of U in part (a)(iv). (4)
- (ii) Draw a section of the polymer X showing one repeating unit. (You may use a block diagram for this answer.) (2)
- (iii) Both compounds U and X are polymers. Which one of these two compounds would have a lower environmental impact? Give reasons for your answer. (3)
- (Total: 20 marks)**















