



FORM TP 2005177

TEST CODE 02112010

MAY/JUNE 2005

CARIBBEAN EXAMINATIONS COUNCIL
ADVANCED PROFICIENCY EXAMINATION

CHEMISTRY

UNIT 1 – PAPER 01

1 hour 45 minutes

Candidates are advised to use the first 15 minutes for reading through this paper carefully. Writing may begin during this time.

READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This paper consists of NINE questions.
2. There are THREE questions from each Module. Answer ALL questions.
3. Write answers in this booklet.
4. ALL working must be shown in this booklet.
5. The use of non-programmable calculators is permitted.
6. A Data Booklet is provided.

MODULE 1

Answer ALL questions.

1. A chemist is given 1.08 g of a compound labelled X, and is asked to determine the molecular formula and the empirical formula. Analysis of X by mass spectrometry gives a relative molecular mass of 108. Elemental analysis shows that compound X contains carbon, hydrogen and one other element. Among the products obtained when X is burnt completely in oxygen are 1340 cm^3 of CO_2 and 448 cm^3 of NO_2 . [Volumes of gases are measured at s.t.p.]

(a) Define the following terms:

(i) Empirical formula

[1 mark]

(ii) Molecular formula

[1 mark]

(b) Give an example of a compound for which the molecular formula is different from the empirical formula. [You must write the respective formulae.]

[2 marks]

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- (c) Use the data given on page 2 to determine the molecular formula of X.

[6 marks]

Total 10 marks

2. Dry cells (batteries) provide a portable source of energy for many modern appliances. Figure 1 shows some of the components of a dry cell.

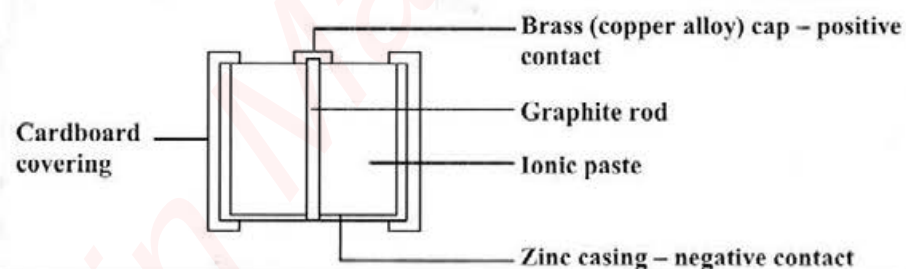


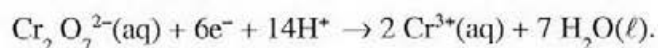
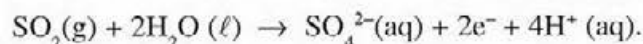
Figure 1. Components of a dry cell

- (a) Referring to the information in Figure 1, explain why the chemical reaction occurring in batteries is described as a redox reaction.

[2 marks]

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- (b) When sulphur dioxide gas is bubbled through acidified potassium chromate (VI), the redox reaction which occurs can be represented by the following half-equations.



- (i) Write the balanced ionic equation for the reaction that occurs.

[2 marks]

- (ii) State the change in oxidation number in any ONE identified reagent in the reaction.

[2 marks]

- (c) Select THREE named elements and describe an experiment, including observations, to show how the elements selected can be listed in order of oxidizing or reducing ability.

[4 marks]

Total 10 marks

3. The kinetic theory was developed to explain the behaviour of gases.

- (a) State the behaviour of gases that is described by

- (i) Boyle's law

[1 mark]

- (ii) Charles' law.

[1 mark]

GO ON TO THE NEXT PAGE

- (b) (i) State TWO assumptions made when the kinetic theory is used to explain the behaviour of gases.

[2 marks]

- (ii) Describe how the kinetic theory explains EITHER Boyle's law OR Charles' law.

[2 marks]

- (c) A certain mass of gas occupies a volume of 1.00 dm^3 at a given pressure and a temperature of 25°C . If the gas behaves ideally, what is its volume at 30°C ? State any assumptions that you make in obtaining your answer.

[4 marks]

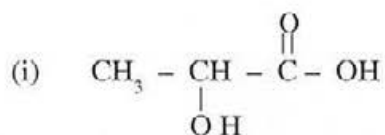
Total 10 marks

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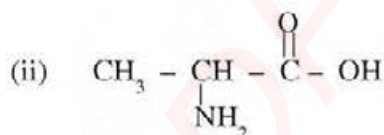
MODULE 2

Answer ALL questions.

4. (a) Some organic compounds contain more than one functional group. Identify ANY TWO functional groups that are present in the following natural products.



(lactic acid)



(alanine)

[2 marks]

- (b) Distinguish between the following terms:

- (i) Electrophiles and nucleophiles

[2 marks]

- (ii) Homolytic and heterolytic bond fission

[2 marks]

- (c) 2-chloro-2-methylpropane ($(\text{CH}_3)_3\text{C Cl}$) reacts with sodium hydroxide in an aqueous solution to give 2-methylpropan-2-ol and sodium chloride.

- (i) Write the chemical equation for this reaction.

[2 marks]

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(ii) Outline the steps involved in the reaction in (c) (i) on page 6, by referring to the

a) bond-breaking step

[1 mark]

b) bond-forming step.

[1 mark]

Total 10 marks

5. Benzene is unreactive with concentrated sulphuric acid even when warmed at 50°C . Its reaction with concentrated nitric acid is slow. However, benzene reacts with a mixture of concentrated nitric acid and concentrated sulphuric acid to produce a good yield of nitrobenzene.

(a) (i) Suggest an explanation for the difference in behaviour of benzene under the stated conditions.

[2 marks]

(ii) Write an equation to illustrate the reaction between sulphuric acid and nitric acid.

[2 marks]

GO ON TO THE NEXT PAGE

- (b) (i) Illustrate the reaction mechanism for the nitration of benzene.

[4 marks]

- (ii) What is the name given to the mechanism outlined in (b) (i)?

[1 mark]

- (c) Nitrobenzene reacts with tin and concentrated hydrochloric acid. State the product formed.

[1 mark]

Total 10 marks

6. (a) Ethanol and ethanoic acid are weak organic acids. The pK_a values of ethanoic acid and ethanol are 4.76 and 15.9 respectively.

- (i) State the meaning of the term pK_a .

[1 mark]

- (ii) Explain the significance of the given pK_a values.

[2 marks]

GO ON TO THE NEXT PAGE

- (iii) Describe the features of EACH of the organic molecules that account for the difference in pK_a values.

[2 marks]

- (b) The amino acids are colourless, crystalline, high-melting solids that are moderately soluble in water. L-threonine ($\text{CH}_3-\text{CHOH}-\text{CHNH}_2-\text{COOH}$) is an essential amino acid which is found in animal protein, for example, eggs and milk.

- (i) Give the displayed formula of the amino acid, L-threonine, in an acidic solution.

[2 marks]

- (ii) Explain why L-threonine has a high melting point and is soluble in water.

[3 marks]

Total 10 marks

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MODULE 3

Answer ALL questions.

7. (a) The application of mass spectrometry in the analysis of unknown compounds involves the vaporization, ionization, separation and detection of the sample. Briefly explain how EACH of these processes is achieved in the mass spectrometer unit.

[4 marks]

- (b) A student synthesizes an organic compound by reacting an acyl halide with an alcohol. The sample is analysed using mass spectrometry and the spectrum obtained is shown in Figure 2.

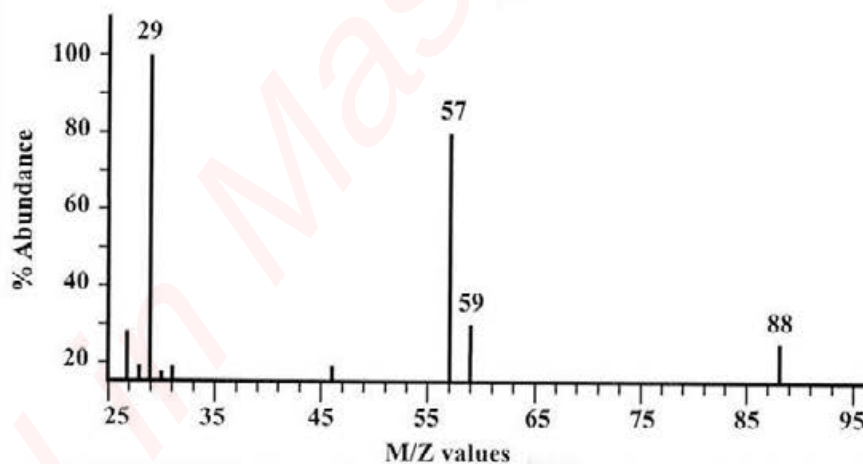


Figure 2. Spectrum

- (i) Give the m/z values of the molecular ion peak and the peak representing the most stable fragment in the spectrum.

[2 marks]

GO ON TO THE NEXT PAGE

- (ii) Suggest possible structures for the fragments with m/z values of 29, 57 and 59.

[3 marks]

- (iii) Deduce the structure of the product of the reaction described in (b) on page 10.

[1 mark]

Total 10 marks

8. Nuclear magnetic resonance (NMR) spectroscopy has become an invaluable tool in the structure elucidation of organic compounds. The underlying principle of this spectroscopic method of analysis is the behaviour of certain nuclei to the application of an external magnetic field.

- (a) (i) Describe the property of the nuclei that allows them to be detected in NMR analysis.

[1 mark]

- (ii) Give the symbols for the TWO main nuclei found in organic molecules that are detected by NMR analysis.

[1 mark]

- (iii) In the acquisition of a NMR spectrum the sample is first subjected to the external magnetic field and then exposed to radio wave signals.
State the changes that occur in the molecules of the sample on this treatment.

[2 marks]

GO ON TO THE NEXT PAGE

- (b) An organic compound of formula $C_9H_{10}O$ is subjected to NMR analysis to determine its structure. The NMR spectrum for the hydrogen atoms displays the following chemical signals:

Chemical Shift (δ)

7.5 (5H)

3.0 (2H)

1.2 (3H)

- (i) Which TWO functional groupings are indicated by the chemical shift values? Explain your reasoning.

[3 marks]

- (ii) Suggest a structure for the organic compound.

[3 marks]

Total 10 marks

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9. Organic reactions can result in a mixture of products, by-products and starting materials. Solvent extraction is often the method applied to isolate the product from the reaction mixture.

- (a) (i) Suggest a type of solvent that could be used to isolate an organic product from an aqueous reaction mixture.

[1 mark]

- (ii) Describe TWO properties the solvent should have for this extraction method to work.

[2 marks]

- (iii) Briefly explain ONE principle on which solvent extraction is based.

[2 marks]

- (b) Plant material is often the source of base material for drug development and natural product preparations. The method of extraction used to obtain the base material should minimize damage to the natural organic molecules and allow for easy collection.

- (i) Suggest a method that would be suitable to extract the natural organic compounds from the plant material.

[1 mark]

- (ii) Give TWO features of the method suggested in (b)(i) that allow the stated objectives of the extraction to be achieved.

[2 marks]

- (iii) Explain why the features mentioned in (b)(ii) above are essential.

[2 marks]

Total 10 marks

END OF TEST