FORM TP 2021197

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CARIBBEAN EXAMINATIONS COUNCIL

CARIBBEAN ADVANCED PROFICIENCY EXAMINATION®

CHEMISTRY

UNIT 2 – Paper 02

2 hours 30 minutes

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This paper consists of THREE questions. Answer ALL questions.
2. Write your answers in the spaces provided in this booklet.
3. Do NOT write in the margins.
4. Where appropriate, ALL WORKING MUST BE SHOWN in this booklet.
5. A data booklet is provided.
6. You may use a silent, non-programmable calculator to answer questions.
7. If you need to rewrite any answer and there is not enough space to do so on the original page, you must use the extra lined page(s) provided at the back of this booklet. **Remember to draw a line through your original answer.**
8. **If you use the extra page(s) you MUST write the question number clearly in the box provided at the top of the extra page(s) and, where relevant, include the question part beside the answer.**

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

Answer ALL questions.

MODULE 1: THE CHEMISTRY OF CARBON COMPOUNDS

1. (a) (i) Define the term 'structural isomerism'.

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[2 marks]

(ii) Identify TWO types of structural isomers, giving an example of EACH.

Type 1 .....

Example .....

Type 2 .....

Example .....

[4 marks]

(b) A gaseous hydrocarbon P, of volume 10 cm^3, of the formula (C_xH_y) was mixed with 70 cm^3 of oxygen and exploded in a reaction chamber. After cooling to room temperature, the gaseous mixture occupied a volume of 55 cm^3. After shaking with aqueous sodium hydroxide, the volume was reduced to 35 cm^3. The remaining gas was shown to be oxygen. (All volumes were measured at constant pressure.) The following equation represents the combustion of P with oxygen.

$$C_x H_y + (x + \frac{y}{4}) O_2 \rightarrow x CO_2 + \frac{y}{2} H_2O$$

(i) Calculate the molecular formula of the hydrocarbon, P.

[3 marks]

GO ON TO THE NEXT PAGE

(ii) Write the displayed structural formula of P.

[1 mark]

(iii) Outline the reaction mechanism for the reaction of P with liquid bromine, using appropriate notations and equations.

[4 marks]

(iv) Identify the type of reaction mechanism outlined in (b) (iii) **on page 5**.

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[1 mark]

(c) Compound Q is an acyclic hydrocarbon of molecular formula C_4H_8.

(i) Write the displayed structural formula of TWO isomers of Q.

Isomer 1 .....

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Isomer 2 .....

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[2 marks]

(ii) State whether Compound Q exhibits geometric (cis/trans) isomerism.

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[1 mark]

(iii) State TWO reasons for your answer in (c) (ii).

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[2 marks]

(iv) Outline the mechanism for the reaction between Compound Q and HBr, using curved arrows to show the movement of electrons.

[4 marks]

(v) State the type of reaction mechanism outlined in (c) (iv).

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[1 mark]

(d) Describe the observations expected for EACH of the following reactions

(i) Aqueous bromine is added to liquid pentane (in sunlight).

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[2 marks]

(ii) Aqueous bromine is added to liquid pentane (without sunlight).

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[1 mark]

(iii) Cold acidified potassium permanganate solution is added to liquid pentane.

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[2 marks]

Total 30 marks

MODULE 2: ANALYTICAL METHODS AND SEPARATION TECHNIQUES

2. (a) Define EACH of the following terms.

(i) Accuracy

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(ii) Precision

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[4 marks]

(b) Sodium hydrogen carbonate ($NaHCO_3$) is sometimes used as a primary standard, yet its molecular mass is only 84 g mol^{-1}.

(i) List THREE reasons why $NaHCO_3$ can be used as a primary standard.

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[3 marks]

(ii) State ONE reason why NaOH may NOT be used as a primary standard.

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[1 mark]

(c) A student standardized a solution of sulfuric acid, using sodium hydrogen carbonate as the primary standard, and found the concentration of the acid to be 5.00 mol dm^{-3}.

(i) Write the balanced equation for the reaction between sodium hydrogen carbonate and sulfuric acid.

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[2 marks]

(ii) Calculate the mass (in grams) of the sodium hydrogen carbonate that the student would use to neutralize the acid, if 23.50 cm^3 of the acid were used from the burette.

[4 marks]

(d) After conducting a titration, a student had the following titre values.

Titre No.	Rough	2nd	3rd	4th	5th	6th
Vol/cm^3	25.95	25.85	25.00	25.25	25.35	25.30

(i) Define the term 'mean volume'.

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[1 mark]

GO ON TO THE NEXT PAGE

(ii) Determine the mean volume from the titre values (to be used in the calculations).

[2 marks]

(iii) Define the term 'standard deviation'.

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[1 mark]

(iv) Using the following equation, justify the choice of the titre values selected in (d) (ii).

$$S = \frac{\sqrt{\Sigma\left(x - \bar{x}\right)^2}}{n-1}$$

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[3 marks]

GO ON TO THE NEXT PAGE

(e) When 0.612 g of hydrated barium chloride is heated to constant mass, 0.522 g of residue is formed. Deduce the formula of hydrated barium chloride.

[4 marks]

(f) To determine the ethanoic acid content of a particular brand of vinegar, a sample of the vinegar was titrated using sodium hydroxide solution.

Outline FIVE experimental steps that should be carried out to determine the ethanoic acid content of the vinegar.

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[5 marks]

Total 30 marks

MODULE 3: INDUSTRY AND THE ENVIRONMENT

3. (a) Figure 1 shows The Haber–Bosch synthesis of ammonia from its elements.

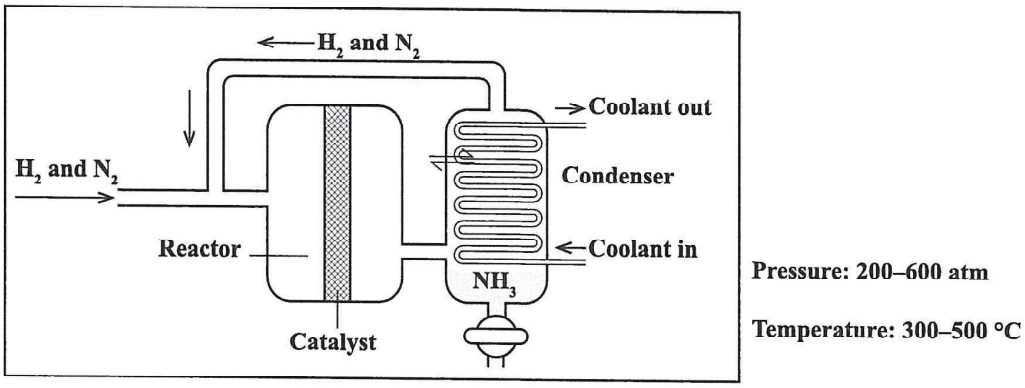

Figure 1. Haber–Bosch synthesis of ammonia

The equation for the synthesis is $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ ($\Delta H^0_f = -92.38$ kJ).

(i) State ONE reason why a catalyst is needed in this reaction.

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[1 mark]

(ii) Using Le Chatelier's principle, explain the effect of temperature on the direction of equilibrium for the ammonia formation.

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[2 marks]

(iii) State whether the temperatures used in the Haber–Bosch synthesis favour the formation of high yields of ammonia.

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[1 mark]

GO ON TO THE NEXT PAGE

(iv) Comment on the statement "High pressure conditions favour the formation of ammonia in high yields."

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[2 marks]

(v) With reference to Figure 1 **on page 13**, state TWO possible design limitations that could lead to reduced product yield.

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[2 marks]

(vi) Write the K_p expression for the Haber–Bosch process.

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[1 mark]

(vii) State the impact of the catalyst on the K_p of the reaction.

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[1 mark]

(b) The use of an Iron-Molybdenum-Sulfur (FeMoS) catalyst is another method of synthesizing ammonia from its elements under standard atmospheric conditions, using UV light in aqueous solvent.

Complete statements (i) to (iv).

In comparison to the Haber–Bosch method, the method above can prove to be

(i) a higher yielding process because .....

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[1 mark]

(ii) a more energy efficient process because .....

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[1 mark]

(iii) a lower cost process because .....

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[2 marks]

(iv) a significant discovery because .....

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[2 marks]

(v) Comment on the statement "The production of ammonia under standard atmospheric conditions would prove to be more efficient in the presence of a catalyst than the Haber–Bosch process."

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[2 marks]

(vi) Identify another feature in the design that makes it 'green', apart from the use of a catalyst in the existing Haber–Bosch process.

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[1 mark]

(c) In recent years, ethanol has been identified as an important industrial resource that has seen a steady increase in production.

(i) In the yeast-catalysed production of ethanol, 60% of the world's ethanol is obtained from the fermentation of sucrose. Write ONE equation that represents a step in this process.

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[2 marks]

(ii) Bioethanol is the name given to ethanol produced from biomass or plant material. Write TWO statements that support the idea that ethanol is a green resource.

Statement 1

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[1 mark]

Statement 2

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[1 mark]

(iii) Sugar cane requires four times more water during ethanol production when compared to sugar beets. State TWO factors that would preclude countries in the Caribbean from considering sugar beets as a viable source crop for ethanol production.

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[2 marks]

(iv) Ethanol is used in mouthwash formulations in addition to active ingredients such as menthol, thymol and eucalyptol. The purpose of these ingredients is to aid in the breakdown of plaque on teeth. Describe the role of ethanol in this process.

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[2 marks]

(v) In a brief experiment, a student sought to make mouthwash by trying a series of formulations. Three of the formulations are listed below. Match EACH formulation using the letters A, B or C with the appropriate set of characteristics that best describes it.

- Formulation A: Deionized water (10%), ethanol (40%), menthol (0.092%), thymol (0.042%), eucalyptol (0.066%)
- Formulation B: Deionized water (40%), ethanol (10%), menthol (0.092%), thymol (0.042%), eucalyptol (0.066%)
- Formulation C: Deionized water (80%), ethanol (5%), menthol (0.092%), thymol (0.042%), eucalyptol (0.066%)

Characteristics	Formulation
Characteristics I: High boiling point, low cooling effect, high viscosity, moderate antimicrobial activity against oral bacteria	
Characteristics II: Low boiling point, strong cooling effect, low viscosity, strong antimicrobial activity against oral bacteria	
Characteristics III: Intermediate boiling point, moderate cooling effect, medium viscosity, intermediate anti-microbial activity against oral bacteria	

[3 marks]

Total 30 marks

END OF TEST

IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK ON THIS TEST.