FORM TP 2021194

TEST CODE 02112020

MAY/JUNE 2021

CARIBBEAN EXAMINATIONS COUNCIL

CARIBBEAN ADVANCED PROFICIENCY EXAMINATION®

CHEMISTRY

UNIT 1 – 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.

0211202003

Answer ALL questions.

MODULE 1: FUNDAMENTALS OF CHEMISTRY

1. (a) Americium-241 is a radioactive isotope used in domestic smoke detectors.

Americium-241 has a half-life of 432 years and decays by emitting alpha particles to produce neptunium.

(i) Define the term 'radioactive isotope'.

.....

.....

.....

.....

[1 mark]

(ii) Give the names and symbols for TWO other forms of radioactive emissions.

.....

.....

.....

[2 marks]

(iii) List THREE uses of radioactive isotopes.

.....

.....

.....

.....

.....

.....

[3 marks]

GO ON TO THE NEXT PAGE

(iv) Determine the value of A and Z in the following equation.

$$^{241}_{95}\text{Am} \rightarrow {}^{A}_{Z}\text{Np} + {}^{4}_{2}\text{He} + \text{energy}$$

[2 marks]

(b) The element rhenium consists of two isotopes ^{185}Re and ^{187}Re, in the atomic ratio of 2:3. Calculate the relative atomic mass of rhenium to three significant figures.

[2 marks]

(c) A student was asked to investigate the relative oxidizing ability of the Group VII element chlorine.

(i) List TWO chemicals and ONE piece of apparatus that the student may use to carry out the investigation.

Chemicals .....

.....

Apparatus .....

.....

[3 marks]

(ii) Describe ONE physical change that the student may observe while carrying out the investigation.

.....

.....

[1 mark]

GO ON TO THE NEXT PAGE

(iii) Identify the oxidizing agent that the student may use while conducting the investigation.

.....

.....

[1 mark]

(iv) Write relevant half equations to illustrate the chemical changes that occur with EACH element used to carry out the investigation.

.....

.....

.....

.....

[2 marks]

(d) Define EACH of the following terms.

(i) Molar mass .....

.....

.....

(ii) Mole .....

.....

.....

[2 marks]

(e) Ammonium sulfate reacts with aqueous sodium hydroxide as shown by the equation below.

$$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$$

A sample of ammonium sulfate was heated with 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide. To ensure that all the ammonium sulfate reacted, an excess of sodium hydroxide was used. Heating was continued until all the ammonia had been driven off as a gas. The unreacted sodium hydroxide remaining in the solution required 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid for neutralization.

(i) Calculate the original number of moles of NaOH in 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide.

[2 marks]

(ii) Calculate the number of moles of HCl in 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid.

[2 marks]

GO ON TO THE NEXT PAGE

(iii) Deduce the number of moles of the unreacted NaOH neutralized by the hydrochloric acid.

Moles of unreacted NaOH .....

[1 mark]

(iv) Calculate the number of moles of NaOH which reacted with the ammonium sulfate.

Moles of NaoH .....

[2 marks]

(v) Use your answer in (e) (iv) to calculate the number of moles and the mass of ammonium sulfate in the sample.

Moles of ammonium sulfate .....

Mass of ammonium sulfate .....

[3 marks]

(vi) Write the ionic equation, including physical states, for the reaction between ammonium sulfate and aqueous sodium hydroxide.

.....

[1 mark]

Total 30 marks

GO ON TO THE NEXT PAGE

MODULE 2: KINETICS AND EQUILIBRIA

2. (a) Table 1 below shows the initial rate of the reaction between Substance Q and Substance R, measured in a series of experiments, with the following rate equation being deduced.

$$\text{rate} = k[Q][R]^2$$

TABLE 1: RATES OF REACTION

Experiment	Initial [Q]/mol dm^{-3}	Initial [R]/mol dm^{-3}	Initial Rate/mol dm^{-3} s^{-1}
1	0.020	0.020	1.2×10^{-4}
2	0.040	0.040	
3		0.040	2.4×10^{-4}
4	0.060	0.030	
5	0.040		7.2×10^{-4}

(i) Using the data from Experiment 1, calculate a value for the rate constant, k, and state its units.

Rate constant, k .....

[3 marks]

(ii) Complete Table 1 above by inserting the missing initial [Q], initial [R] and initial rate for the reaction between Q and R.

[4 marks]

GO ON TO THE NEXT PAGE

(iii) The order of the reaction with respect to R is 2. State the meaning of the term 'order of reaction' with respect to R.

.....

.....

[1 mark]

(iv) Deduce the overall order of the reaction between Q and R.

.....

[1 mark]

(b) A fixed mass of marble lumps is reacted with dilute hydrochloric acid at a constant temperature. Outline why the rate of the reaction would increase if the lumps of marble are reduced in size.

.....

.....

.....

[2 marks]

(c) When a 0.218 mol sample of hydrogen iodide was heated in a flask of volume V dm^3, the following equilibrium was established at 700 K.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

The equilibrium mixture was found to contain 0.023 mol of hydrogen.

(i) Calculate the number of moles of iodine and the number of moles of hydrogen iodide in the equilibrium mixture.

Number of moles of iodine .....

[1 mark]

Number of moles of hydrogen iodide .....

[2 marks]

GO ON TO THE NEXT PAGE

(ii) Write an expression for K_c for the equilibrium.

.....

.....

[1 mark]

(iii) Calculate the value of K_c at 700 K.

[2 marks]

(iv) Calculate the value of K_c at 700 K for the equilibrium of the reaction.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

[1 mark]

(d) Buffer solutions are necessary in a wide range of applications, ranging from biological systems to industrial processes.

(i) State the meaning of the term 'buffer solution'.

.....

.....

.....

[2 marks]

GO ON TO THE NEXT PAGE

(ii) Identify a reagent which could be added to a solution of ammonia in order to form a buffer solution.

.....

[1 mark]

(iii) Consider the following equation which represents a buffer solution consisting of a weak acid and its conjugate base in water.

$$HA_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + A^-_{(aq)}$$

Explain the effect on the buffer solution if the concentrations of hydrogen ions $[H^+]$ and hydroxide ions $[OH^-]$ are increased separately.

.....

.....

.....

.....

.....

.....

[2 marks]

(iv) Explain how the molecular structure of amino acids relates to their function as buffers in human blood.

.....

.....

.....

.....

.....

.....

.....

[3 marks]

(e) In a laboratory exercise students are asked to determine the pH of a buffer made by the addition of measured quantities of ethanoic acid and sodium ethanoate.

(i) Identify TWO relevant pieces of apparatus and/or materials that may have been used by the students to carry out the experiment.

.....

.....

[2 marks]

(ii) Identify TWO relevant experimental steps that may have been taken by the students to determine the pH of the buffer.

.....

.....

.....

[2 marks]

Total 30 marks

MODULE 3: CHEMISTRY OF THE ELEMENTS

3. The Group II elements and the first row transition elements exhibit certain similarities and distinct differences in their physical and chemical properties.

Table 2 provides information on the first ionization energy (IE), atomic radii (AR), electronic structure (ES) of atom and oxidation number/state (OS) for some of the elements.

TABLE 2: INFORMATION ON THE FIRST IONIZATION ENERGY (IE), ATOMIC RADII (AR), ELECTRONIC STRUCTURE (ES) AND OXIDATION NUMBER/ STATE (OS) FOR SOME ELEMENTS

Element	1st IE (kJ mol^{-1})	AR (nm)	ES	OS
Magnesium	763	0.160		+2
Calcium	590	0.197		
Strontium	548	0.215		
Vanadium	650	0.122		
Chromium	653	0.117		
Manganese	717	0.117	$[Ar]3d^5 4s^2$	
Iron	759	0.116		+2, +3
Cobalt	758	0.116		

(a) (i) Complete Table 2 by inserting the missing electronic structure (ES) and the oxidation state (OS) for EACH element listed. **[5 marks]**

GO ON TO THE NEXT PAGE

(ii) Explain the difference between the trend of the first ionization energy for the Group II elements and the first row transition elements.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

[4 marks]

(b) (i) Account for the difference in oxidation state between vanadium and calcium.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

[4 marks]

(ii) Comment on the following.

Calcium carbonate is more thermally stable than magnesium carbonate.

.....

.....

.....

.....

.....

.....

[2 marks]

(c) (i) Explain the following observation in terms of the stability constant of the complex ion formed.

When concentrated HCl is added to a pink solution of cobalt (II) chloride, the solution turns blue.

.....

.....

.....

.....

.....

[3 marks]

(ii) Write a balanced equation for the reaction in (c) (i).

.....

.....

[2 marks]

GO ON TO THE NEXT PAGE

(d) Ammonium vanadate, NH_4VO_3, is an orange solid. Tests are performed on NH_4VO_3 and certain colour changes are observed.

(i) Complete Table 3 below to show the observations expected for EACH of the tests.

TABLE 3: TESTS ON AMMONIUM VANADATE

Test	Observation
• A few cm^3 of 3M NaOH is added to a small amount of solid NH_4VO_3, followed by a few cm^3 of 3M H_2SO_4.	Colour formed .....
• A few pieces of granulated zinc are then added to the solution above.	Colour changes to ..... then to ..... then to ..... and finally .....

[5 marks]

(ii) Write the formula of the species formed which is responsible for EACH colour observed in (d) (i) in Table 3 **on page 17**.

Colour	Formula of Species
.....	.....
.....	.....
.....	.....
.....	.....
.....	.....

[5 marks]

Total 30 marks

END OF TEST

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