



# MERU UNIVERSITY OF SCIENCE AND TECHNOLOGY

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## University Examinations 2023/2024

FIRST YEAR, FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE CHEMISTRY, BACHELOR OF SCIENCE IN BIOLOGICAL SCIENCES, BACHELOR OF SCIENCE IN BIOCHEMISTRY, BACHELOR OF SCIENCE IN BIOTECHNOLOGY, BACHELOR OF SCIENCE IN EDUCATION SCIENCE

### SCH 3101: PHYSICAL CHEMISTRY 1

DATE: DECEMBER 2023

TIME: 2 HOURS

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INSTRUCTIONS: *answer question one and any other two questions*

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#### QUESTION ONE

- a) Define pressure. From the definition, obtain the SI unit of pressure in terms of SI base units. 2 marks
- b) Define the following terms 4 marks
- i. Brønsted–Lowry acid
  - ii. Spontaneous process
  - iii. State function
  - iv. Perfect/Ideal gas
- c) Give two types of electrochemical cells 2 marks
- d) The standard cell potential at 25 °C is 1.10 V for the reaction

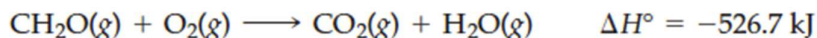
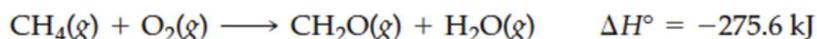


- Calculate the standard free-energy change for this reaction at 25 °C 3 marks
- e) What is effusion? Why does a gas whose molecules have smaller mass effuse faster than one whose molecules have larger mass? 3 marks
- f) Draw a graph showing the distribution of molecular speeds ( $u$ ) for one mole of  $\text{N}_2$  gas at three different temperatures ranging from  $u = 0$  to  $u = 3000\text{m/s}$  5 marks

- g) Methane, the main constituent of natural gas, burns in oxygen to yield carbon dioxide and water:



Use the following information to calculate  $\Delta H^\circ$  in kilojoules for the combustion of methane:

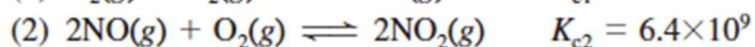
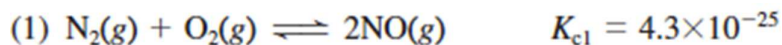


5 marks

- h) Using the concepts developed in this course, explain the following observations.
- Automobile tires are flatter on cold days. 2 marks
  - You are not supposed to dispose of aerosol cans in a fire. 2 marks
  - A balloon pops when you squeeze it. 2 marks

## QUESTION TWO

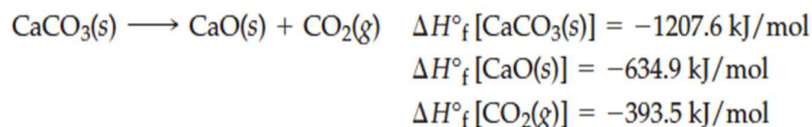
- a) Nitrogen dioxide is a toxic pollutant that contributes to photochemical smog. One way it forms is through the following sequence:



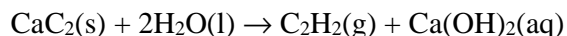
- Show that the overall  $Q_c$  for this reaction sequence is the same as the product of the  $Q_c$ 's for the individual reactions 7 marks
  - Given that both reactions occur at the same temperature, find  $K_c$  for the overall reaction 3 marks
- b) Give the five postulates of kinetic theory and state any evidence based on Boyle's Law and Charles' Law that supports them 10 marks

## QUESTION THREE

- State Hess's Law 2 marks
- Calculate  $\Delta H^\circ$  in kilojoules for the synthesis of lime (CaO) from limestone (CaCO<sub>3</sub>), the key step in the manufacture of cement 5 marks



- c) State Dalton's Law of partial pressure 3 marks
- d) Acetylene ( $\text{C}_2\text{H}_2$ ), an important fuel in welding, is produced in the laboratory when calcium carbide ( $\text{CaC}_2$ ) reacts with water:



For a sample of acetylene collected over water, total gas pressure (adjusted to barometric pressure) is 738 torr and the volume is 523 mL. At the temperature of the gas ( $238^\circ\text{C}$ ), the vapor pressure of water is 21 torr. How many grams of acetylene are collected? 10 marks

#### QUESTION FOUR

- a) To identify the contents of an unlabelled cylinder of gas, a sample was collected and found to have a density of 5.380 g/L at  $15^\circ\text{C}$  and 736 mm Hg pressure. What is the molar mass of the gas? 6 marks
- b) A 1.00-L sample of dry air at  $25^\circ\text{C}$  and 786 mmHg contains 0.925 g  $\text{N}_2$ , plus other gases including oxygen, argon, and carbon dioxide.
- i. What is the partial pressure (in mmHg) of  $\text{N}_2$  in the air sample? 6 marks
  - ii. What is the mole fraction and mole percent of  $\text{N}_2$  in the mixture? 3 marks
- c) Calculate the relative mean square speed of  $\text{O}_2$  molecules in a cylinder at  $21^\circ\text{C}$  and 15.7 atm,  $R = 8.31 \text{ kg}\cdot\text{m}^2/(\text{s}^2\cdot\text{K}\cdot\text{mol})$ . 5 marks