



# MACHAKOS UNIVERSITY

University Examinations 2016/2017

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

FIRST YEAR SECOND SEMESTER EXAMINATION FOR DEGREE IN  
BACHELOR OF SCIENCE IN ELECTRICAL & ELECTRONIC ENGINEERING  
BACHELOR OF SCIENCE IN CIVIL AND BUILDING ENGINEERING  
BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

ECU 102: CHEMISTRY FOR ENGINEERS II

DATE: 13/6/2017

TIME: 8:30 – 10:30 AM

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## INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

## Required Data

- $R = 8.314 \text{ JK}^{-1}\text{mol}^{-1} = 0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$
- $1 \text{ atm} = 760 \text{ mmHg}$

## **Provided:**

Periodic table

## SECTION A – COMPULSORY (30 MARKS)

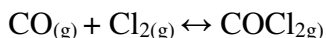
1. a) i) Derive the Van der Waals' equation of state from ideal gas equation. (3 marks)  
ii) A sample of 4.37 moles of  $\text{Cl}_2$  gas is confined in a volume of 2.45 L at 38 °C. Calculate the pressure of the gas (in atm) using:

I) The ideal gas equation (2 marks)

II) The Van der Waals' equation of state given  $a = 6.49 \text{ atm L}^2 \text{ mol}^{-2}$  and  $b = 0.0562 \text{ L mol}^{-1}$ . (3 marks)

- b) A compound was found to contain 49.98 g carbon and 10.47 g hydrogen. The molecular mass of the compound is  $58.12 \text{ g mol}^{-1}$ . Determine the molecular formula (4 marks)

- c) i) State the Le Chatelier's principle. (1 mark)  
ii) Carbonyl Chloride ( $\text{COCl}_2$ ) also called phosgene was used in the World War I as a poisonous gas. The equilibrium concentrations for the reaction between carbon monoxide and molecular chlorine to form carbonyl chloride (equation below)

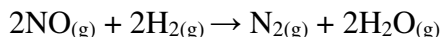


at 74 °C are  $[\text{CO}] = 1.2 \times 10^{-2} \text{ M}$ ,  $[\text{Cl}_2] = 0.054 \text{ M}$  and  $[\text{COCl}_2] = 0.14 \text{ M}$ . Calculate:

- I) The equilibrium constant  $K_c$  (3 marks)  
II) The value of  $K_p$  at 500 °C (2 marks)  
III) Explain the effect of i) increasing pressure ii) adding a catalyst to the above reversible equation (2 marks)
- d) i) State the Dalton's Law of partial pressures (1 mark)  
ii) A mixture of gases contains 4.46 moles of neon (Ne), 0.74 moles of argon (Ar) and 2.15 moles of Xenon (Xe). Calculate the partial pressures of the gases if the total pressure is 2.00 atm at a certain temperature. (3 marks)
- e) Explain **four** factors that affect the rate of a chemical reaction (6 marks)

**SECTION B : ANSWER ANY TWO QUESTIONS (20 MARKS EACH)**

2. a) The reaction of nitric oxide with hydrogen at 100 °C is presented as:



From the following data collected at 25 °C:

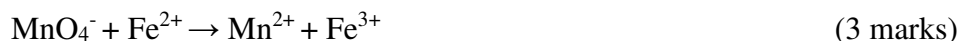
Experiment	[NO] (M)	[H <sub>2</sub> ] (M)	Initial Rate (M/s)
1	5 x 10 <sup>-3</sup>	2 x 10 <sup>-3</sup>	2.5 x 10 <sup>-5</sup>
2	10 x 10 <sup>-3</sup>	2 x 10 <sup>-3</sup>	5 x 10 <sup>-5</sup>
3	10 x 10 <sup>-3</sup>	4 x 10 <sup>-3</sup>	10 x 10 <sup>-5</sup>

Determine the:

- I) Rate law (4 marks)
- II) Rate constant (2 marks)
- III) The rate of the reaction when [NO] = 1.2 x 10<sup>-3</sup> M and [H<sub>2</sub>] = 6.0 x 10<sup>-3</sup> M (3 marks)
- b) Ethyl iodide (C<sub>2</sub>H<sub>5</sub>I) decomposes at a certain temperature in the gas phase as follows:  
C<sub>2</sub>H<sub>5</sub>I<sub>(g)</sub> → C<sub>2</sub>H<sub>4(g)</sub> + HI<sub>(g)</sub>. The following data was obtained.

Time (min)	0	15	30	48	75
[C <sub>2</sub> H <sub>5</sub> I] (M)	0.36	0.30	0.25	0.19	0.13

- i) Determine if the above data support a first order reaction. (4 marks)
- ii) Calculate the rate constant for the reaction. (2 marks)
- c) Define a half-life (t<sub>1/2</sub>) of a reaction and show that for a 1<sup>st</sup> order rate reaction, the half life (t<sub>1/2</sub>) is independent of the initial concentration (5 marks)
3. a) i) Write the balanced net ionic equation for the reaction in an acidic medium by the ion-electron method:



- ii) Identify the oxidizing and the reducing agent in the above equation (2 marks)

- b) An electrochemical cell is made up of electrodes M and N with the half-cell reactions:



- i) Determine the half- reaction that occurs at the cathode, anode and the overall cell reaction (3 marks)

- ii) If the  $[Cu^{2+}] = 0.15 \text{ M}$  and  $[Zn^{2+}] = 0.25 \text{ M}$  for the above cell, calculate the EMF of the cell at  $25 \text{ }^\circ\text{C}$ . (3 marks)
- iii) Draw a conventional schematic diagram of the cell using separate beakers for each half cell. Label the anode, cathode and the other components of the cell. Indicate the flow of the electrons (5 marks)
- iv) Explain **two** applications of electrolytic cells (2 marks)
- d) State the Nernst equation and define all the terms (2 marks)
4. a) The concentration of  $H^+$  ions in a bottle of wine was  $3.2 \times 10^{-4} \text{ M}$  right after the cork was removed. Only half of the wine was consumed. The other half, after it had been standing open to the air for a month was found to have a  $H^+$  concentration of  $1 \times 10^{-3} \text{ M}$ .
- i) Define the pH of a solution (2 marks)
- ii) Calculate the pH of the wine on the two occasions (4 marks)
- b) Sodium ethanoate was added to  $0.2 \text{ mol dm}^{-3}$  ethanoic acid until the concentration of the salt was  $0.05 \text{ mol dm}^{-3}$ . Given that the  $K_a$  for ethanoic acid is  $1.74 \times 10^{-5} \text{ mol dm}^{-3}$ , Calculate the pH of the solution formed. (4 marks)
- c) Derive the Henderson – Hasselbalch equation (4 marks)
- d) Urea can be synthesised in the laboratory by the combination of ammonia and carbon dioxide according the equation:
- $$NH_3(g) + CO_2(g) \rightarrow (NH_2)_2CO_{(aq)} + H_2O(l)$$
- i) Calculate the amount of urea that will be produced by the complete reaction of 5.25 moles of ammonia (3 marks)
- ii) Determine the stoichiometric amount of carbon dioxide required to react with 5.25 moles of ammonia (3 marks)
5. a) i) Define colligative properties (1 mark)
- ii) State four examples of colligative properties (2 marks)
- b) i) State Raoult's law (include the mathematical expression) (2 marks)
- ii) Vapour pressure of chloroform ( $CHCl_3$ ) and dichloromethane ( $CH_2Cl_2$ ) at  $298 \text{ K}$  are  $200 \text{ mm Hg}$  and  $415 \text{ mm Hg}$  respectively. A solution was prepared by mixing  $25.5 \text{ g}$  of  $CHCl_3$  and  $40 \text{ g}$  of  $CH_2Cl_2$  at  $298 \text{ K}$ . (RMM of  $C = 12$ ,  $H = 1$ ,  $Cl = 35.5$ ).

Calculate;

- i) The number of moles of  $\text{CH}_2\text{Cl}_2$  (1 mark)
  - ii) The number of moles of  $\text{CHCl}_3$  (1 mark)
  - iii) The total number of moles (1 mark)
  - iv) The mole fractions of  $\text{CH}_2\text{Cl}_2$  and  $\text{CHCl}_3$  (1 mark)
  - v) The vapour pressure of the solution (1 mark)
- c) i) State Henry's law (1 mark)
- ii) List two conditions for applicability of Henry's law (2 marks)
- d) i) Define an ideal solution. (1 mark)
- ii) Briefly describe the properties of an ideal solution. (2 marks)
- e) It takes nitrogen gas 2 minutes to diffuse through an orifice. Calculate the time that methane ( $\text{CH}_4$ ) gas will take to diffuse through the same orifice. (4 marks)