

# MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING, SCIENCE AND TECHNOLOGY

DEPARTMENT: CHEMICAL AND PROCESSING ENGINEERING

MODULE: PHYSICAL CHEMISTRY FOR ENGINEERS

CODE: ENGT 104

SESSIONAL EXAMINATIONS

JUNE 2023

DURATION: 3 HOURS

EXAMINER: MR M. MAPOSA

---

## INSTRUCTIONS

1. Answer *Any four* Questions
2. All questions carry equal number of marks
3. Start a new question on a fresh page
4. Total marks 100

*Additional material(s): Chemistry data booklet, Graph paper*

---

## QUESTION 1

**In this question you can use the following constants:**

**Planck's Constant =  $6.63 \times 10^{-34}$  Js, Electron mass =  $9.11 \times 10^{-31}$  kg,  $1 \text{ eV} = 1.602 \times 10^{-19}$  J, speed of light =  $3 \times 10^8$  m/s**

- a) Explain the following observations made during a photoelectric investigation
- (i) electrons ejected from the same metal surface during photoelectric emission have different kinetic energies
  - (ii) the intensity of light incident on a metal surface increases the number of ejected electrons
  - (iii) frequency of the incident light increases the kinetic energy of the ejected electrons
  - (iv) only light of a certain minimum frequency can result in photoelectric emission
  - (v) different metals have different work functions [10]
- b) Calculate the maximum kinetic energy, (KE) and velocity of an electron ejected from zinc by a 250 nm photon, given that zinc has a work function of 4.31 eV [4]
- c) Determine by means of a calculation whether a photon of wavelength 300 nm incident on a zinc surface would result in photoelectric emission or not [4]
- d) A beam of light of frequency  $3.13 \times 10^{15}$  Hz incident on a silver surface gave out photo electrons with maximum kinetic energy of 8.22 eV. Deduce the work function of silver [4]
- e) State any three applications of photoelectric effect [3]

## QUESTION 2

- a) De Broglie is one of the scientists who contributed significantly to the idea of wave particle duality. He made it possible to calculate the wavelength of any moving object.
- i. Give the De Broglie expression
  - ii. Calculate the de Broglie wavelength of
    - 1 a 2 tonne car traveling at a speed of 45 m/s
    - 2 An electron travelling at a speed of 100 m/s
  - iii. Explain fully why the wavelength of the car is insignificant to consider
  - iv. At what velocity in m/s would that 2 tonne car travel so as to have the same wavelength as an electron travelling at 100 m/s [12]
- b) State the strengths of Raman spectroscopy over other molecular spectroscopic techniques [6]
- c) Draw a schematic diagram to show the components of a single beam UV-VIS spectrometer [4]
- d) State any two strengths and one limitation of UV-VIS spectroscopy [3]

## QUESTION 3

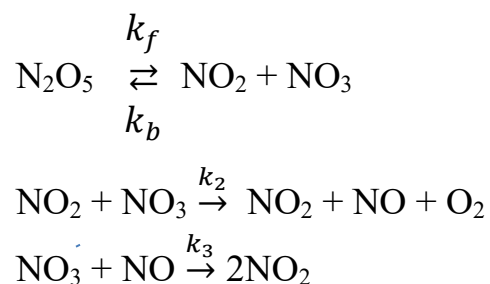
- a) Briefly describe the significance of the following concepts in the study of reaction kinetics
- i) Collision theory
  - ii) Complex reaction
  - iii) Chain initiation
  - iv) Activation energy
  - v) Arrhenius equation [10]
- b) The following data of rate constants was collected at different temperatures from a series of experiments carried out on the reaction:  $2\text{N}_2\text{O}_5 \rightarrow 2\text{N}_2\text{O}_4 + \text{O}_2$

T/K	298	308	318	328	338
K (s <sup>-1</sup> )	1.74x10 <sup>-5</sup>	6.66x10 <sup>-5</sup>	2.51x10 <sup>-4</sup>	7.59x10 <sup>-4</sup>	2.40x10 <sup>-3</sup>

- i) Copy and complete the table by creating space for the values of ln k and 1/T
- ii) Plot a graph of ln k against 1/T
- iii) Use your graph to find a value for the activation energy of the reaction
- iv) What would be the rate constant k if this same reaction was carried out at 350 K [12]
- c) Briefly distinguish between unimolecular elementary step and bimolecular elementary step showing the nature of the rate law in each case [3]

#### QUESTION 4

- a) Compare and contrast
- i) Reaction intermediate and a transition state
- ii) Reaction mechanism and reaction profile
- iii) Lindeman theory and RRKM theory in the kinetics of gaseous reactions [12]
- b) The reaction of dinitrogen pentoxide to produce nitrogen dioxide and oxygen has the following mechanism



Use steady state approximation to deduce the expression for the

- i) Concentration of the intermediate *NO*

- ii) Concentration of the intermediate  $NO_3$
- iii) Rate of the overall reaction in terms of change in concentration of  $N_2O_5$
- iv) Overall rate constant  $K$  in terms of  $k_f$ ,  $k_3$ ,  $k_2$  and  $k_b$  [13]

### QUESTION 5

a) Beer's law can be used to evaluate concentration from absorbance of an analyte.

- i) State Beer's law and highlight the significance of each term
- ii) The calibration curve used to analyse the concentration of a pollutant in the effluent had a line of best fit represented by the equation;

$$y = 0.998x + 0.01.$$

Calculate the concentration of the pollutant in an effluent sample which gave an absorbance reading of 0.06.

- iii) In another different experiment, phenol concentration was analysed using UV-VIS. A sample of concentration  $0.05 \text{ mol dm}^{-3}$  gave an absorbance value of 412 using cells of pathlength one centimeter. Deduce a value for the molar absorptivity ( $\epsilon$ ) with correct units. [12]

b)  $CO_2$  is an ir active molecule.

- i) Explain fully the meaning of this statement
- ii) Calculate the degrees of freedom for the vibrations of the following

molecules

1.  $CO_2$
2.  $SO_2$
3.  $CH_3CH_3$

[13]

**END OF EXAMINATION**