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 x10^{-34}Js, Electron mass = 9.11 x 10^{-31} kg, 1 eV = 1.602 x 10^{-19}J, speed of light = 3 x 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 x 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: $\mathbf{2N_2O_5 \rightarrow 2N_2O_4 + O_2}$

T/K	298	308	318	328	338
K (s^{-1})	$1.74x10^{-5}$	$6.66x10^{-5}$	$2.51x10^{-4}$	$7.59x10^{-4}$	$2.40x10^{-3}$

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

$$N_2O_5 \underset{k_b}{\overset{k_f}{\rightleftarrows}} NO_2 + NO_3$$

$$NO_2 + NO_3 \xrightarrow{k_2} NO_2 + NO + O_2$$

$$NO_3 + NO \xrightarrow{k_3} 2NO_2$$

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 moldm^{-3} gave an absorbance value of 412 using cells of pathlength one centimeter. Deduce a value for the molar absorptivity (**ε**) 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