MACHAKOS UNIVERSITY

University Examinations 2022/2023

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

THIRD YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)

BACHELOR OF EDUCATION (SPECIAL NEEDS)

BACHELOR OF EDUCATION (SCIENCE)

SPH 302: STRUCTURE AND PROPERTIES OF MATTER

DATE: 20/4/2023 **TIME: 8:30 – 10:30 AM**

INSTRUCTIONS:

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

CONSTANTS

1 Å	=	10^{-10} m
1 eV	=	1.6×10^{-19} J
1 a. m. u	=	1.66×10^{-27}
Avogadro's number	=	6.023×10^{26} kgmol^{-1}
Coefficient of viscosity	=	0.0089 cmgs

SECTION A

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Define the following terminologies encountered in the study of crystal structures.

i. Crystalline lattice (2 marks)

ii. Basis (2 marks)

b) State two precautions made in the Kinetic theory of gases (2 marks)

c) Express the intercepts (1, -2,1) of a plane ABC in miller indices. (3 marks)

d) State two assumptions made in the formulation of Poiseulli's equation for a flowing fluid. (2 marks)

e) Calculate the glancing angle on a cube (1 0 0) of a rock salt crystal where the lattice constant a = 2.814 Å corresponding to the 2nd diffraction maximum for an X-ray of wavelength $\lambda = 0.732$ Å. (5 marks)

f) Matter exists in three main states as well as other states which are closely related to the three states. Briefly discuss these other states. (5 marks)

g) The molar specific heats of an ideal gas at a constant pressure and volume are denoted by C_p and C_v, respectively. Given that $\gamma = \frac{C_p}{C_v}$ and R is universal gas constant. Show that $C_V = \frac{R}{\gamma - 1}$. (3 marks)

h) Calculate the mass of water flowing in 20 minutes through a tube of diameter 6.1 cm and 40 cm long if there is a constant pressure head of 20 cm of water. (3 marks)

i) A metal plate of area $2.5 \times 10^{-4} m^2$ is placed on a $0.25 \times 10^{-4} m$ thick layer of castor oil. If a force of 2.5 N is needed to move the plate with a velocity $3 \times 10^{-2} m\, s^{-1}$, calculate the coefficient of viscosity of castor oil. (3 marks)

SECTION B

QUESTION TWO (20 MARKS)

a) Define

i. Packing factor (2 marks)

ii. Coordination number (2 marks)

b) The molar specific heat of oxygen at constant pressure $C_p = 7.03$ cal/mol^{o}C and R = 8.31 J/mol^{o}C. Find the amount of heat taken by 5 mol of oxygen when heated at a constant volume from 10^{o}C to 20^{o}C. (3 marks)

c) A sodium-chloride (NaCl) unit cell comprising of four molecules consist of sodium ion and chloride ion joined along the cube edges of the cell. Its basis consists of 2 ions; one of sodium and the other of chloride. Given that;

Radius of sodium ion = 0.98 Å

Radius of chloride ion = 1.81 Å

Atomic mass of Sodium = 22.99 a.m.u

Atomic mass of Chlorine = 35.45 a.m.u

Calculate;

i. The lattice parameter a (3 marks)

ii. Packing factor f (5 marks)

iii. Density of NaCl (5 marks)

d) Derive the Poiseville's equation. (5 marks)

QUESTION THREE (20 MARKS)

a) Define molar specific heat capacity (2 marks)

b) One mole of a diatomic ideal gas at a temperature of 310 K expands adiabatically from an initial volume of 12.0 L to a final volume of 19.0 L. What is the final temperature of the gas? (3 marks)

c) A substance with a Face Centered Crystal (F.C.C) lattice has a density of 6250 kg/m^3 and molecular weight of 60.2 a.m.u. calculate the lattice constant a. (5 marks)

d) An X-ray beam of wavelength 0.81 Å is diffracted by a cubic potassium chloride (KCl) crystal of density 1.99×10^3 kg/m^3. Calculate;

i. The inter planer spacing for (3 4 0) planes (5 marks)

ii. The glancing angle for the 2nd order reflection from these planes given that the molecular weight of KCl is 74.6 a.m.u. (5 marks)

QUESTION FOUR (20 MARKS)

a) Define

i. Symmetry operations (2 marks)

ii. Bravais lattice (2 marks)

b) State the Bernoulli's theorem (2 marks)

c) State three assumptions made in the derivation of Stoke's law. (3 marks)

d) Derive the Stoke's law using the dimensions method. (5 marks)

e) A vessel containing 1 g of oxygen is at a pressure of 10 atm and a temperature of 47^{o}C. It is found that because of a leak, the pressure drops to 5/8th of its original value and the temperature falls to 27^{o}C. Find:

i. The volume V of the vessel (3 marks)

ii. The mass of the leaked oxygen (3 marks)

QUESTION FIVE (20 MARKS)

a) 40 calories of heat are required to raise the temperature of an ideal mono-atomic gas from 20^{o}C to 30^{o}C at a constant pressure. Find the amount of heat required to raise its temperature over the same interval at a constant volume (R = 2 cal/mol^{-1}K^{-1}) (5 marks)

b) Given that the potential energy of two atoms is given by the expression $U = \frac{-A}{r^2} + \frac{B}{r^{10}}$ and that a stable molecule is formed with release of 10 eV of energy when the inter atomic distance is 2.8 Å, determine;

i. The values of A and B (5 marks)

ii. The inter-atomic distance at which the dissociation occurs (r_c) (5 marks)

iii. The force needed to dissociate this molecule into molecules (5 marks)

c) Derive the Bernoulli's theorem in terms of pressure heads (5 marks)