KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR

THIRD YEAR FIRST SEMESTER
SUPPLEMENTARY/SPECIAL EXAMINATIONS

FOR THE DEGREE OF BSC (PURE PHYSICS)

COURSE CODE: SPC 311

COURSE TITLE: SOLID STATE PHYSICS

DURATION: 2 HOURS

DATE: ~~18~~/11/2022 **TIME:** 8:~~00AM-10:00AM~~

INSTRUCTIONS TO CANDIDATES

- Answer **QUESTION ONE** (Compulsory) and any other two (2) Questions.
- The following constants might be used: mass of electron= 9.1×10^{-31} kg; electronic charge=1.6×10^{-19} C; Planck's constant= 6.62×10^{-34} JS; atomic mass of Lithium= 1.152×10^{-26} kg; Boltzmann's constant =8.63×10^{-5} eV/k

QUESTION ONE [30 Marks]

a) What kind of bonds do you expect in the following materials: Magnesium chloride, carbon, solid argon, Zinc Sulphide, Germanium and ice? [3]

b) Define the coordination number as applied in crystallography [2]

c) Determine the number of atoms per unit cell for the body centered cubic cell [4]

d) Draw diagrams showing the following directions and planes for a cubic crystal [100], [010], [001], [111], [110], (200) and (101) [4]

e) If you have a 1 cm^3 of aluminum, how many vacancies would it contain at 300K if the energy needed to create the vacancy is 0.75 eV and there are 10^{22} atomic in every cubic centimeter of the sample? [3]

f) Define a lattice plane (Crystal plane). [2]

g) Calculate the Miller indices of crystal planes which cut through the crystal axes at

i) (6a, 3b, 3c)

ii) (2a, -3b, -3c) [4]

h) Describe briefly the formation of an ionic bond. [2]

i) Given that the spacing between the adjacent planes of atoms ($d_{(hkl)}$) for cubic crystal is $d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$ what is the lowest energy that will allow Bragg diffraction to occur during an electron diffraction experiment from the plane {111}from planes of silicon crystal which has a lattice parameter a equal to 0.542 nm? [6]

QUESTION TWO [20 Marks]

a) i) Define ionization energy and electron affinity. [2]

ii) Sketch (111) and (110) planes in simple cubic cell. [2]

iii) Determine the structure factor in a body centered cubic CsCl unit cell. [3]

b) Show that Laue and Bragg condition are equivalent. [5]

c) Calculate the distance between two lattice planes, which give first order diffraction at an angle of 26.4^0 with a wavelength 0.75Å. [3]

d) An fcc crystal can be described by the following four sets of atomic coordinates: 000, 0 ½ ½, ½ 0 ½ , 1/2 0 ½ and ½ ½ 0. Is there a Bragg reflection (i.e. a reflection that satisfies the Bragg law) from the (100) plane of an fcc crystal? [3]

QUESTION THREE [20 Marks]

a) Distinguish between Einstein's theory of specific heat of solids and Debye's theory and hence define Einstein temperature. [5]

b) The Bragg angle corresponding to the first order reflection from (111) planes in a crystal is 30^0 when x-rays of wavelength 1.75 Å are used. Calculate the interatomic spacing. [3]

c) Bragg found that KCl crystal strong reflection from set of planes (100), (110) and (111) are obtained for angles 5.38^0,7.62^0 and 9.41^0. Show that KCl crystal has a simple cubic structure. [4]

d) KCl is an example of an ionically bonded crystal for which the cohesive energy per ion pair may be written as

$U(r) = A\exp(\frac{-r}{\rho}) - \frac{\alpha Z^2}{4\pi\varepsilon_0 r^2}$, where r is the nearest neighbor distance, Z is the ionic charge.

I) Explain the origins of the two terms and the meaning of the symbols A, ρ and α. [4]

II) For a crystal of KCl, calculate the cohesive energy per ion pair relative to the separated neutral gas atoms, expressing your answer in units of eV. (For KCl, $A=2.05\text{x}10^{-15}$. P=0.326Å, r=3.147Å, α=1.748, K has first ionization energy of 4.34 eV, Cl an electron affinity of 3.16 eV). [4]

QUESTION FOUR [20 Marks]

a) Which type of bonding is likely to be present in the following solids. Briefly explain the origins of the bonds.

I) Xenon (Xe) [2]

II) Cesium bromide (CsBr) [2]

III) Copper (Cu) [3]

IV) Silcon (Si) [2]

b) Calculate the mass density of Lithium (Li), which has a lattice parameter of 0.350nm. (Lithium has a bcc crystalline structure) [4]

c) Show that the atomic radius r a simple cubic crystal (sc) is given by r=a/2 and for a body centered cubic (bcc) crystal is given by $r = \frac{a\sqrt{3}}{4}$ where a is the lattice parameter. [7]

QUESTION FIVE [20 Marks]

a) Give the meaning of lattice and basis. Explain simple cubic, body centered cubic, face centered cubic lattice structures. [10]

b) The total energy of an ionic solid is given by an expression $E = \frac{-\alpha e^2}{4\pi\varepsilon_0 r} + \frac{B}{r^9}$ where α is the Madelung constant, r is the distance between the nearest neighbor in crystal and B is a constant. If r_0 is the equilibrium separation between the nearest neighbor, determine the value of B. [5]

c) Calculate the packing fraction of the body-centered cubic structure. [5]

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