UNIVERSITY OF GHANA

FACULTY OF ENGINEERING SCIENCES

BSc. (ENG) MATERIALS SCIENCE AND ENGINEERING

END OF SECOND SEMESTER EXAMINATIONS: 2012/2013

MTEN 312: CRYSTAL CHEMISTRY OF CERAMICS (3 CREDITS)

TIME ALLOWED: THREE (3) HOURS

Answer ALL Questions

Question 1

a) Briefly cite the main differences between ionic, covalent, and metallic bonding.

b) Explain why covalently bonded materials are generally less dense than ionically or metallically bonded ones.

c) State the Pauling and Heisenberg uncertainty principle.

d) Explain why hydrogen fluoride (HF) has a higher boiling temperature than hydrogen chloride (HCl) (19.4°C versus -85°C), even though HF has a lower molecular weight.

e) The following ceramics; Al_2O_3, ZrO_2, Y_2O_3, diamond and SiC are hard with high melting temperatures. What type of bonding exists in these ceramics?

14 Marks

Question 2

a) **Figure 1** has two different crystal packings; (i) for a non-dense or random packing and (ii) is for dense packing. Sketch graphically their energy (E) versus their inter-particles distances (r) and comment on these two parameters with respect to the structural packing in (i) and (ii).

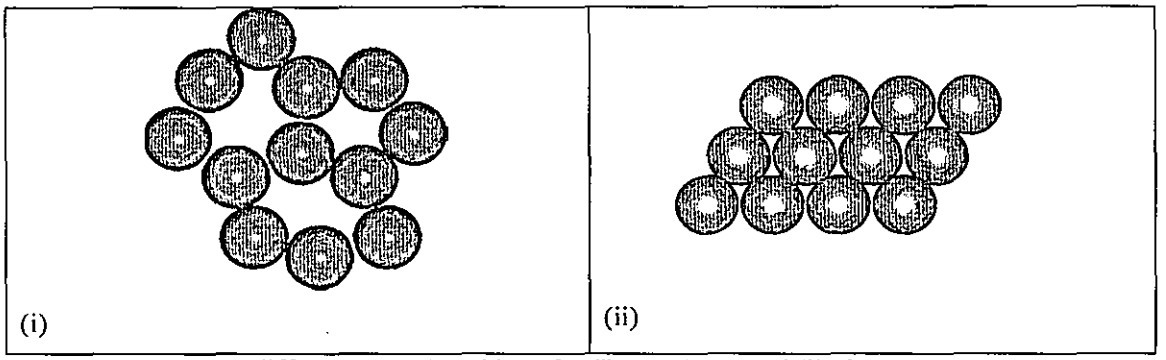

Figure 1. Two different crystal packings for (i) non-dense and (ii) dense

b) Magnesium Oxide and Sodium Chloride have the following electronegativity differences: Mg = 1.2, O = 3.5, Na = 1.5, Cl = 3.0. Estimate the % Ionic character in each of the preceding compounds.

c) Sodium chloride (NaCl) exhibits predominantly ionic bonding. The Na^+ and Cl^- ions have electron structures that are identical to which two inert gases?

d) What is the difference between atomic structure and crystal structure?

e) The ceramic materials Gypsum ($CaSO_4$) and Zircon ($ZrSiO_4$) have two bonding combinations. What are they?

16 Marks

Question 3

a) Show that, for the body-centered cubic crystal structure the unit cell edge length a, and the atomic radius R, are related through, $a = 4R/\sqrt{3}$.

b) For the HCP crystal structure, show that the ideal ratio c/a is 1.633.

c) Assuming a cubic crystal system, make a sketch of the following planes

(001), (111), (123), $(\bar{1}10)$, (010), $(\bar{1}\bar{1}\bar{1})$, $(0\bar{1}0)$.

d) What information is needed to specify a crystal structure?

e) The unit cell for Tin has tetragonal symmetry, with 'a' and 'b' lattice parameters of 0.583 and 0.318 nm, respectively. If its density, atomic weight, and atomic radius are 7.27 g/cm^3, 118.71 g/mol, and 0.151 nm, respectively, compute the atomic packing factor.

18 Marks

Question 4

a) Write out the symmetry elements present in the 'molecules' in **Figure 2** and the corresponding point group of each one. Assume that the molecules are planar, exactly as drawn, and not three-dimensional. The shapes are: (i) pentagonal C_5H_5, in ferrocene; (ii) linear, CS_2; (iii) triangular, SO_2; (iv) square, XeF_4.

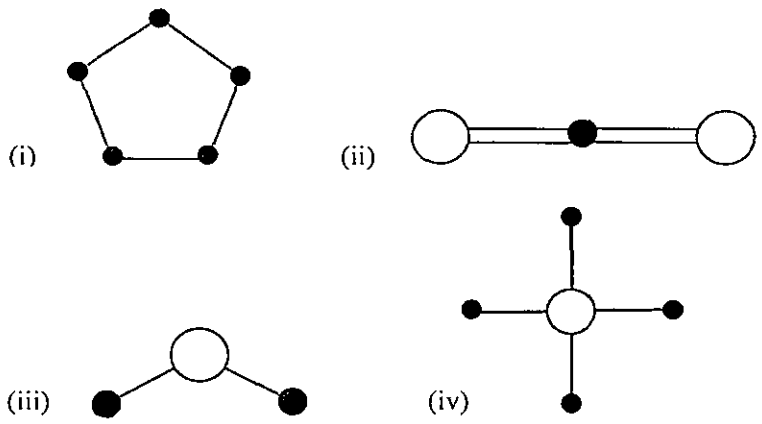

Figure 2. Molecular structures for (i) C_5H_5 (ii) CS_2 (iii) SO_4 and (iv) XeF_4

b) Why do we use x-rays to examine crystal structures?

c) The metal iridium has an FCC crystal structure. If the angle of diffraction for the (220) set of planes occurs at 69.22° (first-order reflection) when monochromatic x-radiation having a wavelength of 0.1542 nm is used, compute;

(i) Interplanar spacing for this set of planes and

(ii) Atomic radius for an iridium atom.

d) An x-ray diffraction pattern for α-iron taken using a diffractometer and monochromatic x-radiation having a wavelength of 0.1542 nm is shown in **Figure 3**; each diffraction peak on the pattern has been indexed. Compute the interplanar spacing for each set of planes indexed; also determine the lattice parameter of Fe for each of the peaks.

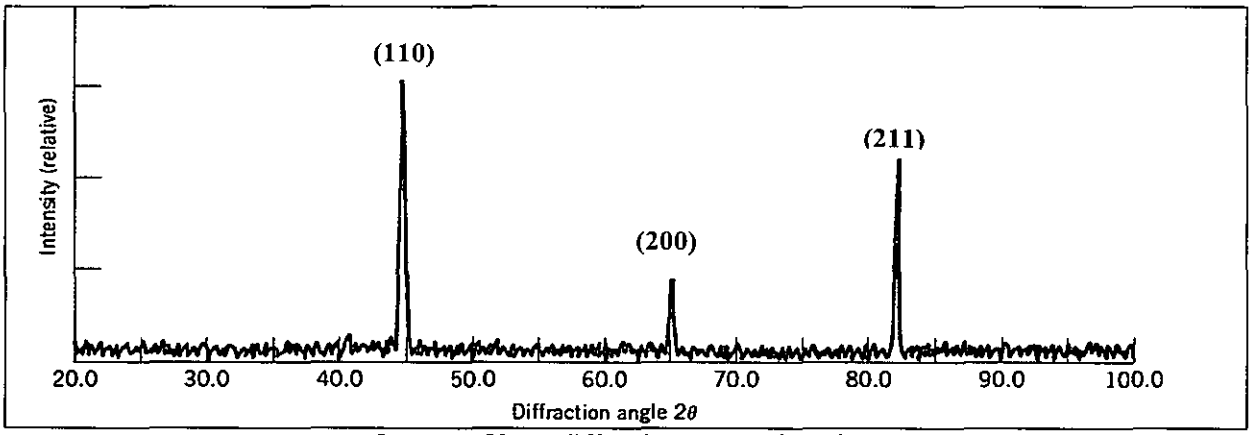

Figure 3. X-ray diffraction pattern for α-iron

(e) Sketch the lattice structure of Kaolinite and Montmorillonite minerals. What separates the lattice structure of a Montmorillonite mineral from that of Mica?

22 Marks