ENGG2120 Fall 2011

Chapter 12: Assignment with Answers

1. For a ceramic compound, what are the two characteristics of component ions that determine the crystal structure?

Answer:

The two characteristics of component ions that determine the crystal structure of a ceramic compound are:

1) the magnitude of the electrical charge on each ion

2) the relative sizes of the cations and anions.

2. Would you expect Frenkel defects for anions to exist in ionic ceramics in relatively large concentrations? Why or why not?

Answer:

Frenkel defects for anions would not exist in appreciable concentrations because the anion is quite large and is highly unlikely to exist as an interstitial.

3. Calculate the number of Frenkel defects per cubic meter in zinc oxide at 1000 ˚C. The energy for defect formation is 2.51 eV and the density for ZnO is 5.55 g/cm^3 at the above mentioned temperature.

Answer:

Number of lattice points per cubic meter (N)

$$N = \frac{N_A \rho}{A_{Zn} + A_O}$$

$$= \frac{(6.022 \times 10^{23}\ \text{atoms/mol})(5.55\ \text{g/cm}^3)(10^6\ \text{cm}^3/\text{m}^3)}{65.41\ \text{g/mol} + 16.00\ \text{g/mol}}$$

$$= 4.11 \times 10^{28}\ \text{lattice sites/m}^3$$

Number of Frenkel defects per cubic meter is given by

$$N_{fr} = N \exp\left(-\frac{Q_{fr}}{2kT}\right)$$

$$= (4.11 \times 10^{28} \text{ lattice sites/m}^3) \exp\left[-\frac{2.51 \text{ eV}}{(2)(8.62 \times 10^{-5} \text{ eV/K})(1000 + 273 \text{ K})}\right]$$

$$= 4.43 \times 10^{23} \text{ defects/m}^3$$

4. Calculate the fraction of lattice sites that are Schottky defects for sodium chloride at its melting temperature (801°C). Assume energy required for defect formation is 2.3 eV.

Answer:

Number of Schottky defects is given by

$$N_S = N \exp\left(-\frac{Q_s}{2kT}\right)$$

By rearranging above equation to get N_S/N ratio

Fraction of lattice sites that are Schottky defects is given by

$$\frac{N_s}{N} = \exp\left(-\frac{Q_s}{2kT}\right)$$

Given the energy for defect formation is 2.3 eV

Temperature = 801^{o}C

$$\frac{N_s}{N} = \exp\left[-\frac{2.3 \text{ eV}}{(2)(8.62 \times 10^{-5} \text{ eV/K})(801 + 273 \text{ K})}\right]$$

$$\frac{N_s}{N} = 4.03 \times 10^{-6}$$

5. In case of ceramic materials why tensile strength measurement becomes difficult compared to polymers and metals?

Answer:

Ceramic materials are very brittle, generally contains lots of micro-cracks. The presence of these micro-cracks is very difficult to control, resulting in amplification of applied tensile stress but it does not occur with the compressive loads. Owing to this ceramic materials are subjected to flexural tests.

6. A Frenkel defect is composed of which of the following?

A) An interstitial and a cation vacancy

B) A cation interstitial and an anion interstitial

C) A cation vacancy and an anion vacancy

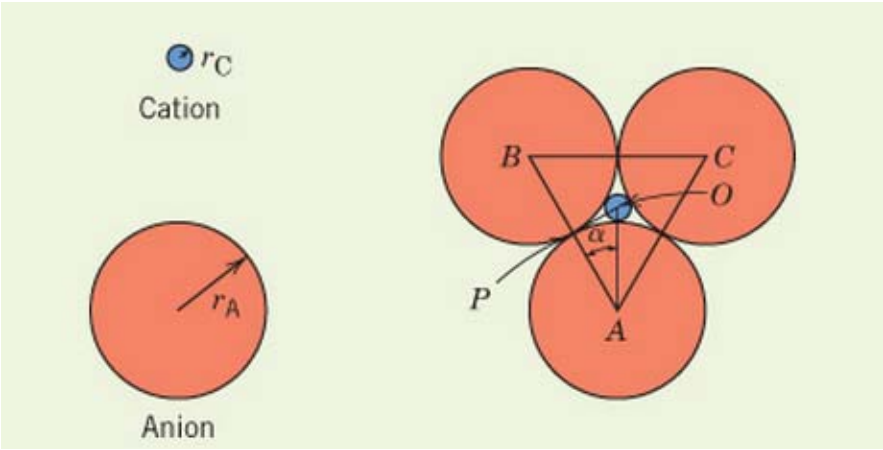
D) An anion interstitial and an anion vacancy

Answer: A

7. Show the minimum cation to anion radius ratio for the coordination number 3 is 0.155.

Answer:

For this coordination number, the small cation is surrounded by three anions to form equilateral triangle as shown in figure triangle ABC; the centres of corners of all four ions are coplanar.



In the figure the right angle triangle APO makes it clear that side lengths are related to anion and cation radii r_A and r_C as

$\overline{AP} = r_A$

$\overline{AO} = r_A + r_C$

The side length ratio $\frac{\overline{AP}}{\overline{AO}}$ is a fraction of angle α as

$\frac{\overline{AP}}{\overline{AO}} = \text{Cos } \alpha$

The magnitude of angle is 30^o because the line $\overline{AO}$ bisects the 60^o angle BAC.

Thus

$\frac{\overline{AP}}{\overline{AO}} = \frac{r_A}{r_A + r_C} = \text{Cos } 30^o = \frac{\sqrt{3}}{2}$

Solving this

$2r_A = \sqrt{3}\ (r_A + r_C)$

$(2-\sqrt{3})\ r_A = \sqrt{3}\ r_C$

$$\frac{r_C}{r_A} = \frac{2-\sqrt{3}}{\sqrt{3}} = 0.155$$

7. State true or False

"The equilibrium number of vacancies for a given quantity of material depends on temperature and increases with temperature"

Answer: True

8. The coordination number is related to the_____

(a) cation–anion radius ratio.

(b) ratio of the velocity of light in a vacuum to the velocity of light in the ceramics

(c) gravity

Answer:

(a) cation–anion radius ratio

9. State True or False

(a) Electroneutrality is the state that exists when there are equal numbers of positive and negative charges from the ions.

(_____)

(b) % ionic character decreases with difference in electronegativity.

(_____)

Answer:

(a)True

(b)False