
1. For the following questions choose correct answer and/or fill in the blanks.

a) The relationship between defect diffusivity and ionic diffusivity is _____ . The defect diffusivity is much greater than/smaller than (choose one) than the ionic diffusivity because _____ **5**

b) The static dielectric constant is usually larger than/equal to/ smaller (choose one) than the dielectric constant at high frequencies because _____ **4**

c) MgO has a larger than/equal to/ smaller (choose one) refractive index than NaCl because _____ **4**

d) The dielectric constant of MgO is/is not (choose one) a function of temperature because _____

— **3**

e) Removing an ion from the bulk of a solid to its surface is an exothermic/endothermic (choose one) process and occurs because it increases/decreases (choose one) the free energy by increasing/decreasing the _____ . **5**

f) The necessary and sufficient condition(s) for a solid to be:

- an ionic conductor are _____ **2**

- paraelectric solid are _____ **2**

- ferroelectric solid are _____ **2**

- ferrimagnetic solid are _____ **2**

g) Hysteresis is evidence for the presence of _____
because _____

4

h) The surface energy of the (100) in NaCl has a higher/lower (choose one) than the (111) because _____ (HERE YOU HAVE TO SHOW CALCULATIONS) **8**

i) The strengths of ceramics are typically comparable to/smaller than (choose one) the theoretical bond strengths because

_____ **4**

j) Derive the following relationship:

$$\sigma \sqrt{\pi c} = K_{IC}$$

Explain the terms and discuss how you would measure K_{IC} in the lab.

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k) For a solid to be transparent it must _____ and

_____ **5**

l) The addition to PbO to silica glass increases/decreases/does not affect (choose one) its refractive index because

_____ **5**

2. The stiffness of an ionic bond, S_0 , was encountered in Chs. 4, 5 and 14. Explain briefly how or why it was discussed in these chapters. Make sure you clearly explain how S_0 affected the properties of phenomena discussed.

20

3) a) The unit cell of BaTiO_3 is a cubic perovskite and is comprised of octahedra linked to cubo-octahedra. Based on that and other information draw the unit cell of BaTiO_3 . **10**

b) Calculate the density of BaTiO_3 . Make all necessary assumptions.

10

c) At higher temperature BaTiO_3 is paramagnetic /ferrimagnetic /paraelectric /ferroelectric (choose one or more). As temperature is changed a transition occurs. Explain using sketches the nature of that transition. What happens to the dielectric constant, what is the transition temperature usually referred to, etc. What happens at the unit cell level to result in the transformation, if any?

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Information you may find useful:

$r_{\text{O}^{2-}} = 126 \text{ nm}$; $r_{\text{Ti}^{4+}} = 74.5 \text{ nm}$; $r_{\text{Ba}^{2+}} = 175 \text{ nm}$

Atomic wt of O = 16; Ba = 137 g/mol; Ti = 47.9 g/mol.

d) Lead titanate, PbTiO_3 , is a perovskite, wherein the dominant charge carriers are holes. Your boss has entrusted you to **reduce** its electrical conductivity. She proposes you dope the PbTiO_3 with La. There are two ways you can do that; the first is to simply add La_2O_3 to PbTiO_3 . The second is to replace some of the Pb^{2+} ions by La^{3+} ; i.e. form $(\text{La}_x\text{Pb}_{1-x})\text{TiO}_3$. Which approach do you take. (one will get you fired the other promoted). Explain making use of the appropriate defect models. **20**

Hint in one case you add an oxide, in the other just the metal.

Hint for this problem: (not included in exam!)

The logic is: If La substitutes for Pb you create electrons or annihilate holes according to :

The alternative:

would also work by increasing the V_{Pb} which in turn will decrease p...

Ref. Levinson

- 4) a) The dielectric constant is a complex function. Explain what that means. In your words differentiate between the real and imaginary part of the dielectric constant. **10**
- b) Discuss the various polarization mechanisms for the following: Ar gas, water, and MgO. Be specific. Comment on the relative value of the dielectric constant for each material. i.e. rank them **10**
- c) For each of these substances plot the temperature dependence (from 0K to 400 K) of the real and imaginary parts of the dielectric constant. **5**
- d) For each of these substances plot the frequency dependence of the real and imaginary part of the dielectric constant at room temperature for each material. **5**
- 2) a) The above figure appears in Ch. 16 and depicts the various loss mechanisms that occur in optical fibers. Clearly explain what type of losses are denoted by the curves labeled A and B. **10**
- b) Estimate the band gap of this material. **10**
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