21.E: Structure and Bonding in Solids (Exercises)

21.1: Crystal Symmetry and the Unit Cell

21.2: Crystal Structure

21.3: Cohesion in Solids

21.4: Defects and Amorphous Solids

21.5: A Deeper Look: Lattice Energies of Crystals

Conceptual Problems

1. If a great deal of energy is required to form gaseous ions, why do ionic compounds form at all?
2. What are the general physical characteristics of ionic compounds?
3. Ionic compounds consist of crystalline lattices rather than discrete ion pairs. Why?
4. What factors affect the magnitude of the lattice energy of an ionic compound? What is the relationship between ionic size and lattice energy?
5. Which would have the larger lattice energy—an ionic compound consisting of a large cation and a large anion or one consisting of a large anion and a small cation? Explain your answer and any assumptions you made.
6. How would the lattice energy of an ionic compound consisting of a monovalent cation and a divalent anion compare with the lattice energy of an ionic compound containing a monovalent cation and a monovalent anion, if the internuclear distance was the same in both compounds? Explain your answer.
7. Which would have the larger lattice energy—$CrCl_2$ or $CrCl_3$—assuming similar arrangements of ions in the lattice? Explain your answer.
8. Which cation in each pair would be expected to form a chloride salt with the larger lattice energy, assuming similar arrangements of ions in the lattice? Explain your reasoning.
    1. Na^+, Mg^{2+}
    2. Li^+, Cs^+
    3. Cu^+, Cu^{2+}
9. Which cation in each pair would be expected to form an oxide with the higher melting point, assuming similar arrangements of ions in the lattice? Explain your reasoning.
    1. Mg^{2+}, Sr^{2+}
    2. Cs^+, Ba^{2+}
    3. Fe^{2+}, Fe^{3+}
10. How can a thermochemical cycle be used to determine lattice energies? Which steps in such a cycle require an input of energy?
11. Although NaOH and CH_3OH have similar formulas and molecular masses, the compounds have radically different properties. One has a high melting point, and the other is a liquid at room temperature. Which compound is which and why?

Numerical Problems

1. Arrange SrO, PbS, and PrI_3 in order of decreasing lattice energy.
2. Compare BaO and MgO with respect to each of the following properties.
    1. enthalpy of sublimation
    2. ionization energy of the metal
    3. lattice energy
    4. enthalpy of formation

3. Use a thermochemical cycle and data from Figure 7.13, Table 7.5, Table 8.2, Table 8.3 to calculate the lattice energy (U) of magnesium chloride ($MgCl_2$).
4. Would you expect the formation of SrO from its component elements to be exothermic or endothermic? Why or why not? How does the valence electron configuration of the component elements help you determine this?
5. Using the information in Problem 4 and Problem 5, predict whether CaO or $MgCl_2$ will have the higher melting point.
6. Use a thermochemical cycle and data from Table 8.2, Table 8.3, and Chapter 25 to calculate the lattice energy of calcium oxide. The first and second ionization energies of calcium are 589.8 kJ/mol and 1145.4 kJ/mol.

Answers

1. Lattice energy is directly proportional to the product of the ionic charges and inversely proportional to the internuclear distance. Therefore, PrI_3 > SrO > PbS.
2.
3. U = 2522.2 kJ/mol
4.
5. Despite the fact that Mg^{2+} is smaller than Ca^{2+}, the higher charge of O^{2-} versus Cl^- gives CaO a larger lattice energy than $MgCl_2$. Consequently, we expect CaO to have the higher melting point.