ChemTalk

Unit 8: Chemical Bonding

Lattice Energy, Born Haber Cycles, and Predictions

In this worksheet, we will cover Lattice energy, Born Haber cycles, and predictions regarding forces and bonds in different types of solids.

Predictions:
It's important to identify the forces and bonds in different types of solids. There are 4 main types of solids.

Ionic Solids
Solids that are composed of metal and nonmetal. Characterized by their high melting points, and ability to conduct electricity in aqueous and liquid form.

Covalent Solids
Solids that are composed entirely of nonmetals. Characterized by their low melting points and their inability to conduct electricity. The atoms that compose the molecules of these solids are held by covalent bonds. The molecules are held together by intermolecular forces.

Covalent Network solids
Solids that are composed entirely of nonmetals. Characterized by their high melting points and lattice structures. These solids are held together by covalent bonds forming three dimensional networks or layers.

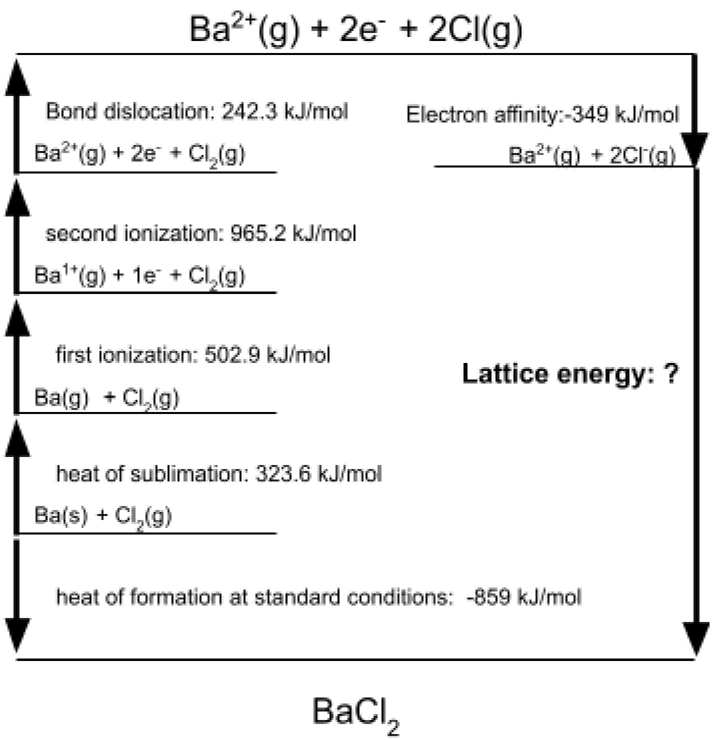
Metallic Solids
Solids that are composed entirely of metals. They have high melting points and can conduct electricity.

1. What is Lattice energy?

2. What determines Lattice energy?

3. Order these 4 compounds from the greatest lattice energy **in magnitude**. Explain.
   $CaCl_2$ NaCl $MgCl_2$ KCl

4. Complete this Born Haber Cycle Diagram.



5. Using the following information calculate the lattice energy of LiBr

$Li(s) + \frac{1}{2} Br_2(g) \rightarrow LiBr(s)$

Ionization Energy of Li: 520 kJ/mol
Electron Affinity of Br: -325 kJ/mol

Sublimation energy of Li: 166 kJ/mol
Vaporization energy of Br_2: 31 kJ/mol
The bond dissociation energy of Br_2: 192 kJ/mol
The heat of formation of LiBr: -345 kJ/mol

6. For the following substances, identify the type of solid they are:

$KMnO_4$		Ag	
CO_2		H_2SO_4	
SO_2		$C_{(graphite)}$	

7. Create a Born Haber Cycle Diagram using the information gathered from question 5.

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ANSWER KEY

1. What is Lattice energy?

Lattice energy is the energy associated with the transformation of one mole of an ionic solid or crystalline lattice of alternating cations and anions into individual gaseous ions.

2. What determines Lattice energy?

Lattice energy is determined by the charge of the ions and the atomic radius. The larger the charge, the greater the lattice energy. The smaller the radius the greater the lattice energy. In addition, charge supersedes distance. So we look at the charge of the ions first before looking at the atomic radius when determining the largest or smallest lattice energy.

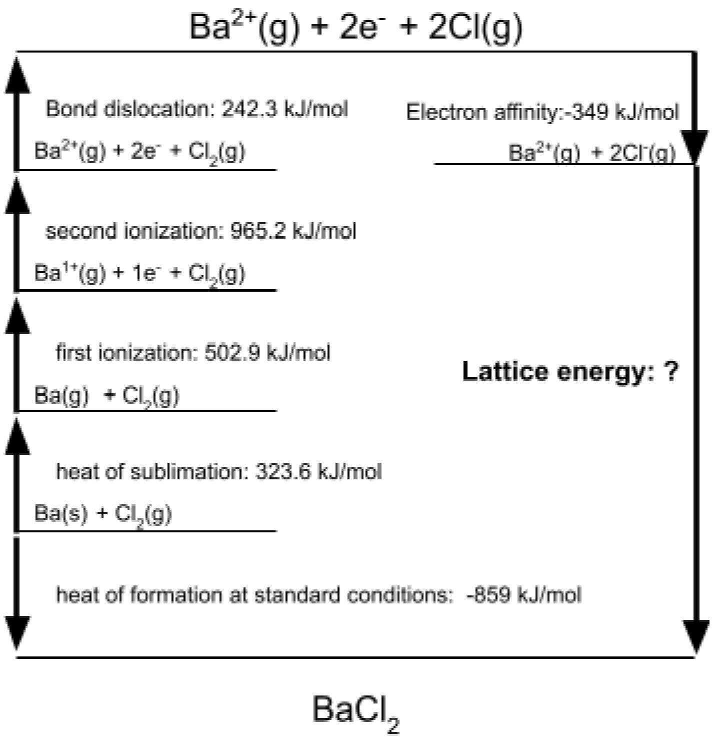
3. Order these 4 compounds from the greatest lattice energy **in magnitude**. Explain.
$CaCl_2$ NaCl $MgCl_2$ KCl

$MgCl_2$ $CaCl_2$ NaCl KCl. Charge supersedes distance. The distance between molecules is so small compared to the charges of ions.
Mg and Ca have a 2+ charge so they have larger lattice energies compared to NaCl and KCl which have a 1+ charge. Now we look at ion radiuses.

Mg and Ca: Mg has a smaller atomic radius than Ca, so the magnitude of the lattice energy of Mg would be larger than Ca.

Na and K: Na has a smaller atomic radius than K, so the magnitude of the lattice energy of Na would be larger than K

4. Complete this Born Haber Cycle Diagram.



The addition of all the changes of enthalpy should equal the heat of formation of the ionic solid at standard conditions.
The Born Haber cycle breaks down the formation into a series of reactions. We add up the energies and set them equal to the net change of enthalpy.

Arrows pointing down are negative and arrows pointing up are positive.
How to add up all the changes of enthalpy:

In order for atoms to become ionized, they must be in a gaseous state.

$323.6kJ/mol$ (Ba is sublimated, and Cl_2 exists as a gas at STP)

Looking at the formula of $BaCl_2$, We can see that it becomes a 2+ ion, meaning it loses 2 electrons. So we add the first and second ionization energies

$323.6\ kJ/mol\ +\ 502.9\ kJ/mol\ +\ 965.2\ kJ/mol$

Next, we need to break the bond between the diatomic Cl_2

$323.6kJ/mol\ +\ 502.9kJ/mol\ +\ 965.2kJ/mol\ +\ 242.3kJ/mol$

The 2 electrons Ba released are taken by the Cl. This releases energy so we add the negative electron affinity values.

$$323.6\ kJ/mol\ +\ 502.9\ kJ/mol + 965.2\ kJ/mol + 242.3\ kJ/mol + (2\ *\ \ -349\ kJ/mol) + x\ kJ/mol\ =\ \ -859 kJ/mol$$

Add values and then isolate x.

$$1336\ kJ/mol\ +\ x\ kJ/mol =\ \ -859\ kJ/mol$$

$$x =-\ 859\ kJ/mol\ -1336\ kJ/mol =\ \ -2195\ kJ/mol$$

In this instance, the lattice energy is negative as the compound is moving from gaseous ions to a crystalline solid rather than from a crystalline solid to gaseous ions in the traditional lattice energy definition.

Therefore, the lattice energy is 2195 kJ/mol

5. Using the following information calculate the lattice energy of LiBr

$Li(s) + ½ Br_2(g) \rightarrow LiBr(s)$

Ionization Energy of Li: 520 kJ/mol
Electron Affinity of Br: -325 kJ/mol
Sublimation energy of Li: 166 kJ/mol
Vaporization energy of Br_2: 31 kJ/mol
The bond dissociation energy of Br_2: 192 kJ/mol
The heat of formation of LiBr: -345 kJ/mol

The addition of all the changes of enthalpy should equal the heat of formation of the ionic solid at standard conditions.
The Born Haber cycle breaks down the formation into a series of reactions. If we add up the energies and set them equal to the net change of enthalpy we can determine any missing enthalpy value like lattice energy.

Be aware of the units and how many moles are being used in the formation reaction.

$$520\ kJ/mol\ +\ (-\ 325\ kJ/mol)\ +\ 166\ kJ/mol\ +\ \frac{1}{2}(31\ kJ/mol)\ +\frac{1}{2}(192\ kJ/mol)\ +\ x =\ \ -345\ kJ/mol$$

As we can see in the above equation, the vaporization energy and bond dissociation energy of Br_2 are multiplied by ½ to account for the number of moles in the equation.

Add values then isolate x.

$472.5\ kJ/mol\ + x = \ -345\ kJ/mol$
$x = \ -345\ kJ/mol\ - 472.5\ kJ/mol = \ -817.5\ kJ/mol$

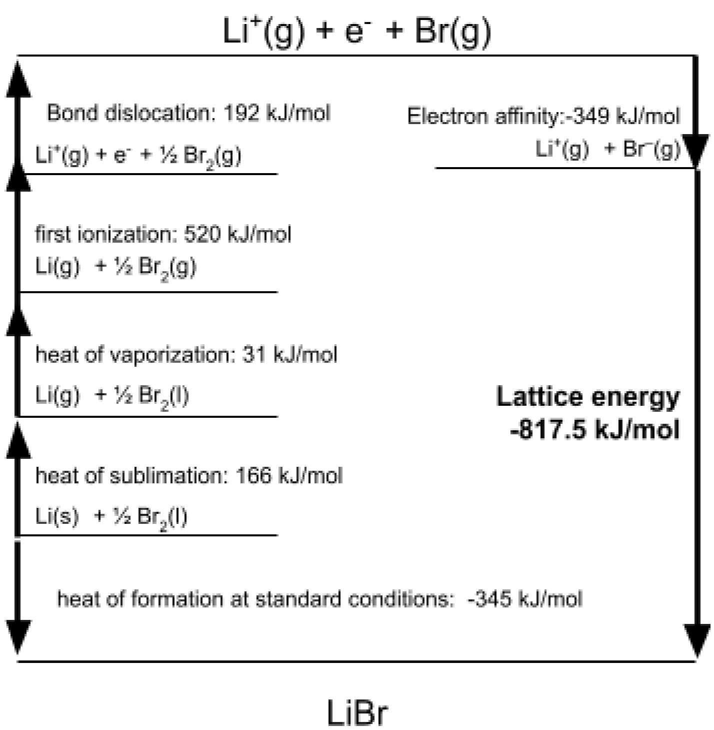
Therefore the lattice energy is 817.5 kJ/mol as we must change the sign to denote a change from solid to gas.

6. For the following substances, identify the type of solid they are:

$KMnO_4$	Ionic Solid K is a metal, MnO_4^- is a non metal containing ion. Ionic solids are the only solid that is composed of both metals and nonmetals.	Ag	Metallic Solid This solid is composed of only metals
CO_2	Covalent Solid This solid is composed of only nonmetals	H_2SO_4	Ionic Solid This solid, although only having nonmetals, H and SO_4 behave like ions as they fully transfer electrons forming ionic bonds. Therefore this is an ionic solid
SO_2	Covalent Solid This solid is composed of only nonmetals	$C_{(graphite)}$	Network covalent solid Carbon forms covalent structures to form graphite.

7. Create a Born Haber Cycle Diagram using the information gathered from question 5.

Sample response:



Remember that in this diagram the lattice energy would be negative as the gaseous ions are forming the ionic solid.