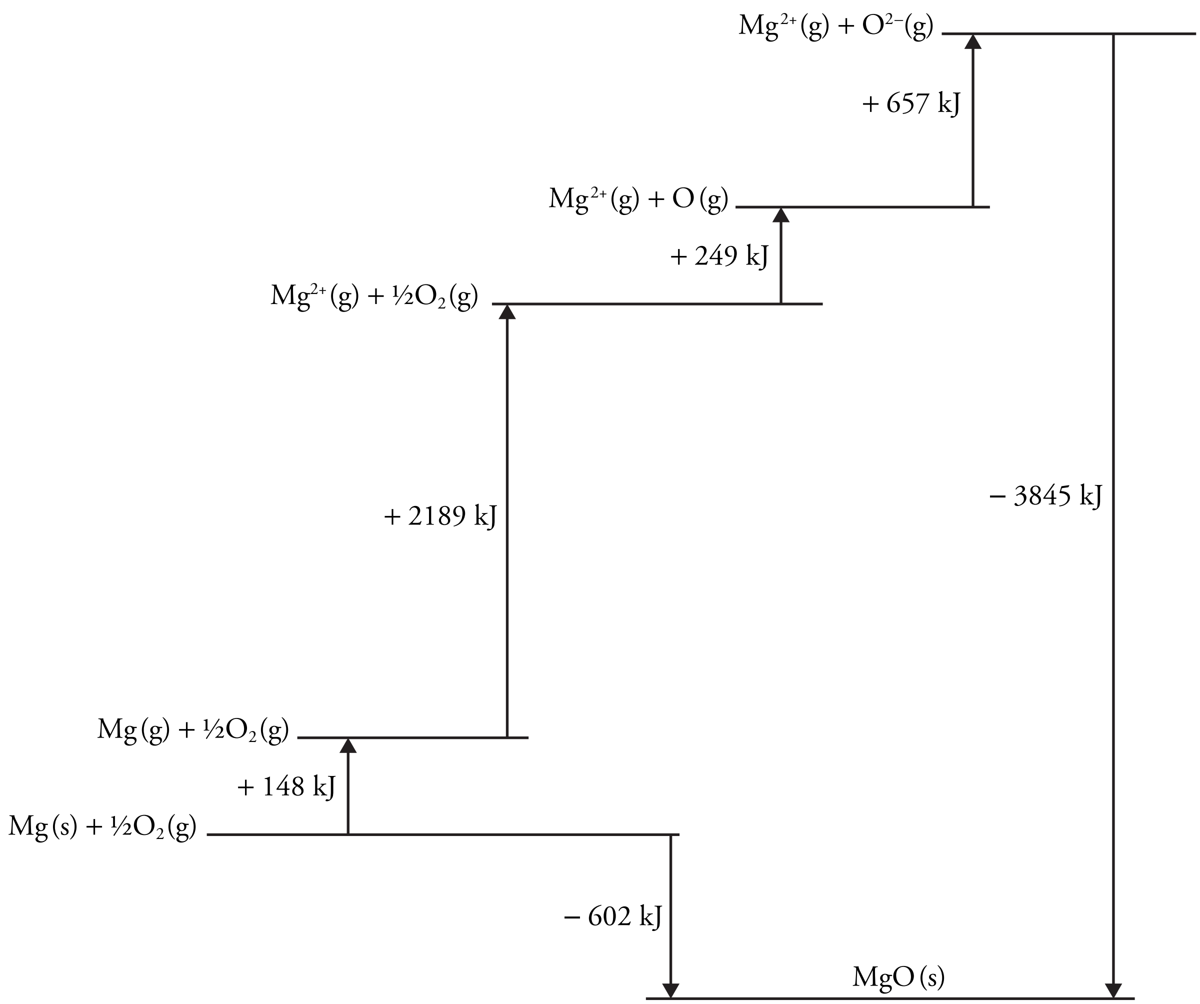
Lattice Energy

How strong are the ionic bonds in an ionic solid?

Why?

When comparing the strengths of covalent bonds we can use bond energy tables to estimate the energy released when a particular bond is formed. The more energy that is released, the stronger, or more stable the bond. Ionic bonds have a similar quantity called **lattice energy**. Lattice energy is defined as the change in energy when ions in their gaseous state form an ionic solid. It is very difficult to directly measure lattice energies for ionic substances, so they are usually theoretically calculated from other data. In this activity, we will look at the variables that determine the magnitude of the lattice energy.

Model 1 – The Born-Haber Cycle



1. What ionic substance is being used to illustrate the concept of lattice energy in Model 1?

2. According to the *Why?* box on the previous page, what is the definition of lattice energy? Label the arrow in Model 1 that represents lattice energy.

3. The lattice energy is theoretically calculated from five other energies. They are listed below with their definitions. Label the remaining arrows in Model 1 with these five energies.
   - 1st and 2nd electron affinity—The energy needed to add two electrons to an atom to form an anion.
   - 1st and 2nd ionization energy—The energy needed to remove an electron from an atom to form a cation.
   - Bond energy—The energy needed to break a covalent bond between atoms.
   - Heat of formation—The energy change when a compound is formed from its component elements in their natural state.
   - Heat of sublimation—The energy needed to change from a solid state into a gaseous state.

4. Verify that the lattice energy shown in Model 1 can be calculated using the five other energy values. Show your calculation here.

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5. If you look up the bond energy for an O_2 molecule, you will find literature values of 498 kJ/mole. Explain why the energy associated with breaking the bonds in the oxygen molecules in Model 1 is listed as half that value.

6. Use the information below to calculate the lattice energy for lithium bromide. *Hint:* Consider that only one bromine atom is needed for lithium bromide. Also consider that Br_2 (l) must be vaporized to Br_2 (g). This heat of vaporization was not necessary in the case of MgO.

$Br(g) + e^- \rightarrow Br^{1-}(g)$	−324 kJ/mole
$Li(g) \rightarrow Li^{1+}(g) + e^-$	+520 kJ/mole
$Br_2(g) \rightarrow 2Br(g)$	+192 kJ/mole
$Br_2(l) \rightarrow Br_2(g)$	+15 kJ/mole
$Li(s) \rightarrow Li(g)$	+162 kJ/mole
$Li(s) + \frac{1}{2}Br_2(l) \rightarrow LiBr(s)$	−351 kJ/mole

7. Consider the definition of lattice energy. Would you predict that lattice energies are always exothermic? Justify your reasoning.

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Model 2 – Atom Size and Charge

Data Set A

	Lattice energy (kJ/mole)
LiCl	–830
NaCl	–770
KCl	–700
RbCl	–680
CsCl	–660

Data Set B

	Lattice energy (kJ/mole)
NaCl	–770
$MgCl_2$	–2530
Na_2O	–2570
MgO	–3930
Al_2O_3	–15270

8. Consider the data presented in Model 2.

   a. Which set of data could be analyzed to show the effect atomic size has on lattice energy? Explain your choice.

   b. Which set of data could be analyzed to show the effect ion charge has on lattice energy? Explain your choice.

9. Refer to Model 2.

   a. As the ions in the solid lattice get bigger, thus making the bond length longer, what happens to the lattice energy of the solid? *Note:* Ignore the sign on the lattice energy. The sign is indicating that energy is released. You are interested in the magnitude of the lattice energy.

   b. Describe how your answer in part *a* relates to the law of Coulombic attraction between charged particles?

10. Refer to Model 2.

   a. When the ions in the solid lattice have higher charges, what happens to the lattice energy of the solid?

   b. Describe how your answer in part *a* relates to the law of Coulombic attraction between charged particles.

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11. Work individually on this question and then discuss your answers as a group. Which compound in each row would have the larger lattice energy? Be prepared to justify your reasoning.

MgO	$MgCl_2$
$MgCl_2$	MgF_2
MgO	CaO
$AlCl_3$	Al_2O_3

12. Match the ionic compounds below to their lattice energy.

Compound	**Lattice Energy kJ/mole**
LiF	–2800
Li_2O	–2240
KF	–1030
KBr	–820
K_2O	–680

Extension Questions

13. The lattice energy (attractive force) of an ionic solid can be approximated using the Coulombic force equation shown below. Use your understanding of lattice energy and Coulombic attraction to answer the following.

$$F = k\frac{q_1 q_2}{r^2}$$

a. Identify each of the variables in the equation.

b. When you calculate the force between a positive and negative ion, will the force be positive or negative? Explain your reasoning.

c. When you calculate the force between two negative ions will the force be positive or negative. Explain your reasoning.

d. How are attractive and repulsive forces distinguished when calculating forces?

14. Most heats of formation for ionic compounds are exothermic—energy is released when the compound forms from its elements in their natural state. However, some are endothermic overall.

a. Refer to Model 1. What must be true about the relative magnitudes of the energies involved in that model to make a heat of formation for an ionic compound endothermic?

b. Would an ionic compound with an endothermic heat of formation be as shelf stable (can be stored for a long time without decomposing) as an ionic compound with an exothermic heat of formation? Explain your reasoning.