Name: _______________

Lattice Energy Guided Inquiry

Background
Lattice energy is the energy needed to break apart the electrostatic attraction between a cation and anion in an ionic crystal lattice. This is an endothermic process (+ΔH kJ/mol). Depending on the scenario, lattice energy can also reference the opposite exothermic process (-ΔH kJ/mol) where an ionic crystal is formed from gaseous ions. The force of attraction that holds the ionic crystal lattice together or needs to be overcome to break it apart is governed by Coulomb’s law. In this activity we will define lattice energy as an endothermic process where the crystal lattice is broken apart. The stronger the force of attraction between ions, the larger the lattice energy.

Problem
How can we use Coulomb’s law to justify lattice energy trends?

Materials
- Colored pencils or markers
- Ruler (mm)

Model 1: Lattice Energy

![Ionic Crystal Lattice of NaF]

Sodium cation, Na\(^{+1}\)
**Model 1 Guided Inquiry Questions**

1. Consider the Sodium Cation found in the box in Model 1.
   a. The arrows in the sodium cation represent forces of attraction felt between ______________________ (cations and anions OR protons and electrons)?
   
   b. The energy needed to overcome this force of attraction is called ______________________ (ionization energy OR lattice energy)?
   
   c. Label the sodium cation box with your answer to the previous question (1b).
   
   d. What law describes the variables that affect the forces of attraction between the particles in the sodium cation?

2. Consider the Ionic Crystal Lattice of NaF in Model 1.
   a. The arrows in NaF represent forces of attraction felt between ______________________ (cations and anions OR protons and electrons)?
   
   b. The energy needed to overcome this force of attraction is called ______________________ (ionization energy or lattice energy)?
   
   c. Label the sodium cation box with your answer to the previous question (1b).
   
   d. What law describes the variables that affect the forces of attraction between the particles in the NaF lattice?

3. Coulomb’s law states that the variables affecting force of attraction are magnitude of charge and distance between charged particles. Analyze the crystal lattice in Model 1.
   a. What part of the crystal lattice shows magnitude of charge?
   
   b. What part of the crystal lattice shows the distance between charged particles?
4. Summarize the differences between using Coulomb’s law to justify ionization energy versus lattice energy in the chart below:

<table>
<thead>
<tr>
<th>Ionization Energy</th>
<th>Lattice Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td></td>
</tr>
<tr>
<td>Charged Particles</td>
<td></td>
</tr>
<tr>
<td>Distance Created By</td>
<td></td>
</tr>
<tr>
<td>Magnitude of Charge Created By</td>
<td></td>
</tr>
</tbody>
</table>

Model 2 continued on next page.
**Model 2: Crystal Lattices**

*Note: Models drawn only to show correct ratio of ions and relative ionic radii. Not fully accurate.*

<table>
<thead>
<tr>
<th>Formula</th>
<th>Model</th>
<th>Lattice Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>BeF$_2$</td>
<td><img src="image1.png" alt="Model" /></td>
<td>3464 kJ/mol</td>
</tr>
<tr>
<td>NaF</td>
<td><img src="image2.png" alt="Model" /></td>
<td>910 kJ/mol</td>
</tr>
<tr>
<td>MgF$_2$</td>
<td><img src="image3.png" alt="Model" /></td>
<td>2926 kJ/mol</td>
</tr>
</tbody>
</table>
Model 2 Guided Inquiry Questions

5. What is similar between all three crystal lattice structures?

6. Using the arrows drawn in NaF in Model 1 as a guide, draw red force of attraction arrows in each cation and anion in Model 2. Follow the guidelines below to ensure the relative sizes of the arrows are drawn correctly.
   a. The arrow should start at the center of the ion.
   b. Every magnitude of charge is one cm. For example, the arrow for Be$^{+2}$ would be 2 cm long while the arrow for F$^{-1}$ or Na$^{+1}$ would be 1 cm long.

7. Consider NaF in Model 2.
   a. What is unique about the crystal lattice of NaF compared to MgF$_2$ and BeF$_2$? List at least 3 things. Consider the formula, model, and lattice energy.
   b. Remember from the Background section of this activity that lattice energy is energy needed to break apart the crystal lattice. A larger force of attraction results in a larger lattice energy. Why is the lattice energy of NaF smaller than the lattice energy of MgF$_2$ or BeF$_2$? Justify using Coulomb’s law.

8. Consider BeF$_2$ and MgF$_2$ in Model 2.
   a. What is different between BeF$_2$ and MgF$_2$? List at least 2 things. Consider the formula, model, and/or lattice energy.
   b. The lattice energies of MgF$_2$ and BeF$_2$ are close, but not the same. Using Coulomb’s law describe why the lattice energy of BeF$_2$ is larger than MgF$_2$. 
c. Consider a situation in which both ionic crystals (BeF₂ and MgF₂) are dissolved in water to form aqueous cations of Be²⁺ and Mg²⁺ in solution. Ion-dipole intermolecular forces of attraction are created between the cations/anions and water. Which aqueous cation, Be²⁺ or Mg²⁺, will interact more strongly with water? Justify using Coulomb’s law.

9. Considering your answers in questions 7 and 8, which variable is most impactful to the magnitude of the lattice energy: size of the ion or the charge of the ion? Justify using evidence from Model 2.

10. Rank the following ionic substances by **increasing** lattice energy: LiCl, MgO, CaO, KCl. Justify your ranking using Coulomb’s law.

11. Summarize how to use Coulomb’s law justification for trends in lattice energy and ionization energy in the chart below.

<table>
<thead>
<tr>
<th>Ionization Energy</th>
<th>Lattice Energy</th>
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<tbody>
<tr>
<td>Definition</td>
<td></td>
</tr>
<tr>
<td>Charged Particles</td>
<td></td>
</tr>
<tr>
<td>Most important Coulomb’s law variable to consider</td>
<td></td>
</tr>
<tr>
<td>Tie-breaker variable</td>
<td></td>
</tr>
</tbody>
</table>
**Conclusion**
In your own words, summarize how Coulomb’s Law can be used to predict and explain trends in lattice energy versus ionization energy.