Essential Question

How are ions arranged in an ionic solid?

What Is an Ionic Solid?

- **Cations (+):** positive ions that form when an atom loses electrons
- **Anions (−):** negative ions that form when an atom gains electrons
- Ionic solids usually form between a metal and a nonmetal.

There is no such thing as a single NaCl molecule.

Coulomb's Law Review

- q_1 **and** q_2 = the charges on the two ions
- r = the distance between the centers of the ions

$$F \propto q_1 q_2 / r^2$$

A Repeating Pattern

- Ions form a regular, repeating pattern called a crystal lattice.
- Each ion is surrounded by ions of the opposite charge.

The pattern keeps going in every direction until it reaches the surface of the crystal.

Maximize Attraction, Minimize Repulsion

- Nearest neighbors have opposite charges, so the attraction is strong.
- Like charges are farther apart, on the diagonals, so the repulsion is weaker.
- Attraction wins, so the energy is as low as possible and the solid is stable.

Key idea: the cations and anions in an ionic crystal are arranged in a systematic, repeating 3-D pattern that maximizes the attraction between opposite charges and minimizes the repulsion between like charges.

A 3-D Array

- The same alternating pattern repeats left to right, up and down, and front to back.
- A single grain of salt contains about 10^{18} ions.

Exam tip: you will not be asked to memorize or name specific crystal structures. You do need to explain why the ions are arranged this way using Coulomb's law.

Ion Size

- Ions get larger down a group, because each one has another shell of electrons.
- Anions are usually larger than cations. A cation has lost electrons (often a whole outer shell), so it shrinks. An anion has gained electrons, which adds electron repulsion, so it spreads out.

In NaCl, the Cl^- ion (181 pm) is almost twice as wide as the Na^+ ion (102 pm).

Drawing Particle Diagrams

1. **Alternate charges:** every ion is surrounded by ions of the opposite charge.
2. **Correct relative sizes:** check the radii. Anions are usually larger than cations.
3. **Correct ratio:** match the formula so the total charge is zero.

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Why Ionic Solids Are Brittle

- A force shifts one layer of ions.
- Like charges line up next to each other.
- The repulsion splits the crystal apart.

Shifting a layer by just one ion puts positive ions next to positive ions and negative ions next to negative ions.

Stronger Attraction, Higher Melting Point

- Larger charges → stronger attraction
- Smaller ions → stronger attraction
- Stronger attraction → higher melting point

To melt an ionic solid, you have to pull the ions away from each other.

Example: Choosing a Particle Diagram

Try it first!

Which particle diagram best represents a layer of solid LiF? Justify your answer.

Diagram: Three particle diagrams labeled A, B, and C. A: small + ions alternating with larger − ions. B: large + ions alternating with small − ions. C: a row of − ions between two rows of + ions.

Example: Comparing Attractions

Try it first!

Use Coulomb’s law to estimate how many times stronger the attraction between ions is in CaO than in KF. Ionic radii: K^+ = 138 pm, F^- = 133 pm, Ca^{2+} = 100 pm, O^{2-} = 140 pm.

Example: Finding the Error

Try it first!

A student drew this particle diagram of solid $MgCl_2$. Identify the error and explain why it is a problem.

Diagram: Student drawing of MgCl2: a 4 by 4 grid of alternating small Mg2+ ions and large Cl− ions, 8 of each.

Big Ideas

- Ionic solids are 3-D arrays of cations and anions.
- The pattern maximizes attraction and minimizes repulsion.
- Particle diagrams need correct charges, sizes, and ratios.
- Stronger attraction → higher melting point.

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