In a crystal lattice, the ionic radius is a measure of the size of the atom's ion. When formed, ionic atoms change in size with respect to their original atom. Cation radii will decrease and the anion radii will increase in size compared to their neutral atoms. Questions such as: “What methodology is used by chemists to measure ionic radii?” and “Are there any non-experimental ways to estimate the size of ionic radii?” will be answered in this module. Accordingly, there are many ways to determine ionic radii.

**Introduction**

In the past, after an atom is ionized, X-ray diffraction is used to measure how much the radius of the atom increased or decreased. However, scientists wanted to use another technique, due to the fact, that X-ray diffraction is difficult to distinguish a boundary between two ions. As a result, the hard sphere model can be used.

**Hard-Sphere model**

The Hard-Sphere model are impenetrable spheres that do not overlap in space. The Hard-Sphere model has been tested by well-known scientists; Landé, Pauling and Goldsmidt. The ion radii measured under crystal state of ionic compound which cations and anions are stacking in pattern as shown below.

![Figure 1: Schematic of the hard-sphere model](image)

The Hard-Sphere model can be applied to metallic and ionic compounds such as NaCl, which is shown below.
In general, scientists use the formula of internuclear distance to test out the radii of ions and compare with the ion radii done on X-ray diffraction:

$$\text{Internuclear distance (d)} = r_{\text{cation}} + r_{\text{anion}}^2$$

*To calculate ion radii, Lande used ionic compound under solid state (ex: NaCl). This will minimize the distribution of electrons.

1. Find the radii of anion ($r^-$) atom.
2. Find internuclear distance (d) between anion and cation.
3. Use Internuclear distance formula to find the $r^+$. 
Figure 3: The Hard sphere model can roughly determine the ion radii.

Periodic Trends

As described earlier, cations are smaller in size compared to their neutral atoms while anions are larger in size. Cations are smaller than its neutral atoms because the positive nuclear charge, which holds the electrons in closer, exceeds the negative charge when a metal atom loses an electron. On the contrary, anions are larger because the electrons are not held as tightly, repulsions of electrons increase, and the electrons spread out more due to nonmetal atoms gaining an electron. Refer to the outside link to learn more about the periodic trends for ionic radii (http://abulafia.mt.ic.ac.uk/shannon/ptable.php).

References

4. "Ionic radii for Group 1 and Group 2 halide, hydride, fluoride, oxide, sulfide, selenide and telluride crystals." Dalton transactions 39.33 (2010):7786-
Outside Links

- [http://abulafia.mt.ic.ac.uk/shannon/ptable.php](http://abulafia.mt.ic.ac.uk/shannon/ptable.php)

Problems

1. What is the most general formula that used to determine the ion radii for hard sphere model?

2. Find radius for Cacium ion in Calcium Chloride (CaCl$_2$). List out all the steps (numbers are not necessary)

3. Determine which is larger:
   a) K$^+$ or Cs$^+$?
   b) La$^{3+}$ or Lu$^{3+}$?
   c) Ca$^{2+}$ or Zn$^{2+}$?

Answers

1. *Internuclear distance* ($d$) = $r_{cation} + r_{anion}$

2. *Find the radii of anion* ($r^-$) *atom*; *Find internuclear distance* ($d$) *between anion and cation*; *Use Internuclear distance formula to find the $r^+$.*

3. a.) Cs$^+$ b.) La$^{3+}$ c.) Ca$^{2+}$