Chemistry I Worksheet: “Atomic and Ionic Radii”

Use what you have learned from the Periodic Trends Lab to answer the following questions. Include energy levels and nuclear charge where appropriate in your explanations.

1. In general, how do the atoms of elements within a group vary in size? (radii)

2. Write unabbreviated electron configurations for the group 1 elements Li and K. Then do the same for the group 16 elements O and S. What relationship exists between these configurations? Explain the cause of the atomic size trends among the elements within the 2 groups.

3. In general, how do the atoms of elements within a specific period vary in size?

4. Write unabbreviated electron configurations for the period 3 elements Na and Cl. What relationship exists between these configurations. Explain the atomic size trends observed among the elements within the same period.

5. How does the size of a Li ion compare with the size of a Li atom? Explain what causes the size difference.

6. In general, how do the sizes of metal ions compare with the sizes of the atoms from which they were formed? Explain the cause of this size difference.

7. In general, how do the sizes of nonmetal ions compare with the sizes of the atoms from which they were formed? Explain the cause of this size difference.

8. In general, how do the ions within a specific group vary in size? Where are exceptions to this trend found?

9. In general, how do the ions within a specific period vary in size? Where are exceptions to this trend found?
10. Complete the following table for sodium, chlorine and their ions: See http://www.chemicool.com for data on atomic and ionic radii. Use the table to answer questions 11 – 17.

<table>
<thead>
<tr>
<th></th>
<th>Na</th>
<th>Na(^+1)</th>
<th>Cl</th>
<th>Cl(^-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of protons</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>number of electrons</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>electron configuration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>number of energy levels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>radius (pm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

11. How do atoms of Na and Cl compare in relative size? Explain the difference.

12. How do Na and Na\(^+1\) compare in relative size? Explain the difference.

13. How do Cl and Cl\(^-1\) compare in relative size? Explain the difference.

14. How do Na\(^+1\) and Cl\(^-1\) compare in relative size? Explain the difference.

15. In general, how would you expect the sizes of the following pairs of atoms and/or ions to compare? Explain the basis for your answer in each case.

   K and Br

   Br and Br\(^-1\)

   K\(^+1\) and Br\(^-1\)

16. Make a general statement about the size of positive ions compared to their corresponding neutral atoms. Explain the cause of this difference.

17. Make a general statement about the size of negative ions compared to their corresponding neutral atoms. Explain the cause of this difference.
Answers to Worksheet on Ionic and Atomic Size Trends

1. The size of atoms increases down a group in the periodic table.

2. **Li**: 1\(s^22s^1\)  
   **K**: 1\(s^22s^22p^63s^23p^4\)  
   **O**: 1\(s^22s^22p^4\)  
   **S**: 1\(s^22s^22p^63s^23p^4\)

K has a greater number of energy levels than Li, which explains the difference in size between the 2 atoms. The same is true for O and S.

3. The size of atoms decreases from left to right across a period.

4. **Na**: 1\(s^22s^22p^63s^1\)  
   **Cl**: 1\(s^22s^22p^63s^23p^5\)

Both of these electron configurations contain the same number of energy levels. The size of these atoms decreases because the number of protons increases from left to right, resulting in an increasing nuclear charge. This greater charge pulls the energy levels closer to the nucleus as the nuclear charge increases.

5. A lithium +1 ion is smaller than a lithium atom because when lithium becomes an ion, it loses its n=2 energy level. The lithium ion then has fewer energy levels than the lithium atom.

6. In general, metal ions are smaller than the atoms that they were formed from because when a metal atom forms an ion, it loses all of the electrons in its highest energy level, resulting in one less energy for the ion compared to the atom.

7. In general, ions of non metal atoms are larger than the atoms that they were formed from because non metals gain electrons when they form ions. The added electrons create greater repulsion, causing all of the electrons to move farther apart, increasing the size of the ion over the atom.

8. In general, the ions within a group increase in size down the group if they are all the same charge, but where they have different charges, the positive ions are smaller than the negative ions.

9. In general, the ions within a period decrease in size from left to right across a period if they are all the same charge, but at the point where the elements start forming negative ions, there is an increase in size, with the ions then continuing to decrease in size.
10.

<table>
<thead>
<tr>
<th></th>
<th>Na</th>
<th>Na⁺¹</th>
<th>Cl</th>
<th>Cl⁻¹</th>
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</thead>
<tbody>
<tr>
<td>number of protons</td>
<td>11</td>
<td>11</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>number of electrons</td>
<td>11</td>
<td>10</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>electron configuration</td>
<td>[Ne]³s¹</td>
<td>[He]²s²²p⁶</td>
<td>[Ne]³s²³p⁵</td>
<td>[Ne]³s²³p⁶</td>
</tr>
<tr>
<td>number of energy levels</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>radius (pm)</td>
<td>157</td>
<td>116</td>
<td>91</td>
<td>167</td>
</tr>
</tbody>
</table>

11. The sodium atom is larger than the chlorine atom because although they both have 3 energy levels, the greater nuclear charge in chlorine makes the atom smaller.

12. The sodium ion is smaller than the atom, because when sodium loses its valence electron to form an ion, it also loses its 3rd energy level.

13. The chlorine ion is larger than the chlorine atom, because adding an additional electron to the 3rd energy level causes the energy level to expand because of the repulsion of the additional electron.

14. The Na⁺ ion is smaller than the Cl⁻ ion because it has 2 energy levels while the chlorine ion has 3 energy levels.

15. a. The potassium atom is larger than the bromine ion because they both have the same number of energy levels but the bromine atom has a greater nuclear charge which pulls the outer energy level closer to the nucleus.

   b. The Br⁻ ion is larger because it has 1 more electron than the Br atom, which results in all of the electrons in the outer energy level to move further apart because they repel each other.

   c. The Br⁻ ion is larger than the K⁺ ion because the K⁺ ion has 1 less energy level than the Br⁻ ion.

16. Positive ions are smaller than the atoms that they are formed from because when positive ions are formed, an energy level is lost.

17. Negative ions are larger than the atoms that they are formed from because when electrons are added to an atom, the additional repulsion causes the electrons to move further apart in the outer energy level.