Ionic Compounds (Salts)

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(Chemistry Notes)

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Ions and Ionic Compounds

If electrons are added to or removed from a neutral atom, an **ion** is formed.

When an atom or molecule loses electrons it becomes positively charged. Positively charged ions are called **cations.**

$$X - n\,e^{-} = X^{n+}$$

When an atom or molecule gains electrons it becomes negatively charged. Negatively charged ions are called **anions.**

$$X + n\,e^{-} = X^{n-}$$

Predicting Ionic Charges
An atom or molecule can lose more than one electron.

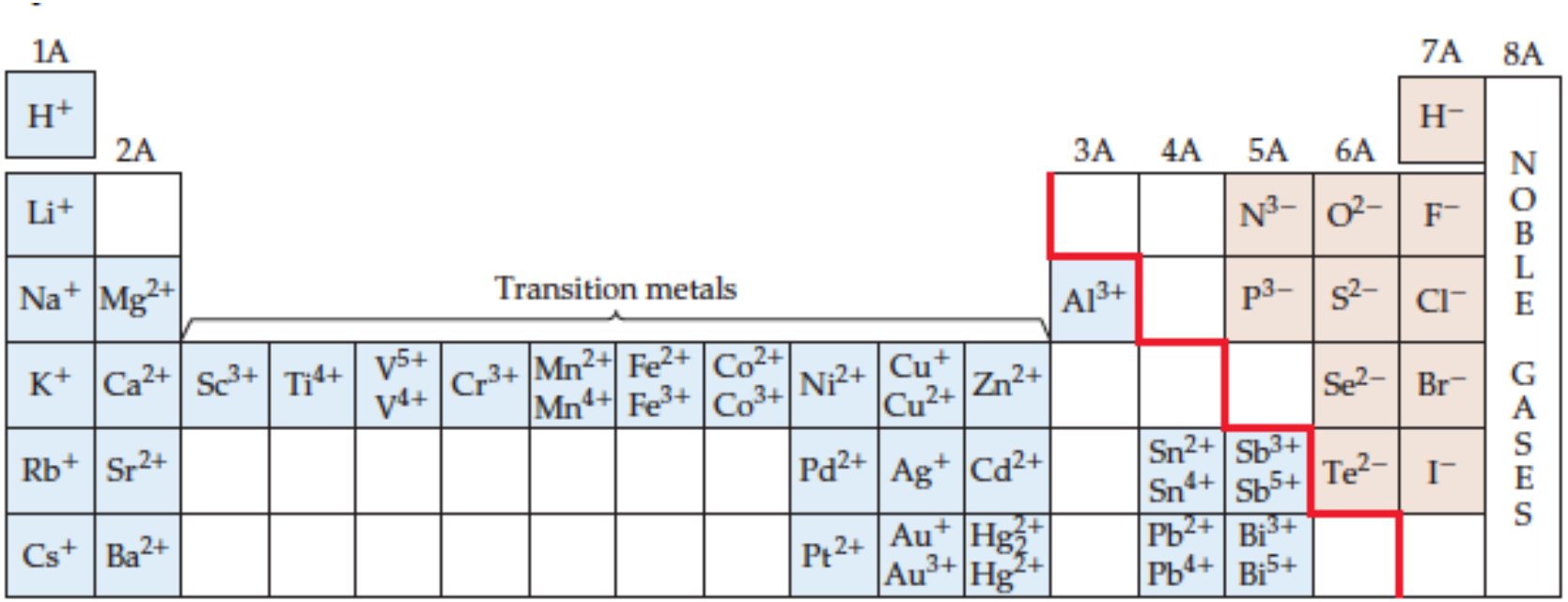
Many atoms gain or lose enough electrons to have the same number of electrons as the nearest noble gas (group 8A).

The number of electrons an atom loses is related to its position on the periodic table.

Summary

Group #	Ion Formed	Equation	Example (name)
Group 1A	X^{+}	$X - 1\ e^{-} = X^{+}$	**K** $^{+}$ (potassium ion)
Group 2A	X^{2+}	$X - 2\ e^{-} = X^{2+}$	**Mg** $^{2+}$ (magnesium ion)
Group 3A	X^{3+}	$X - 3\ e^{-} = X^{3+}$	**Al** $^{3+}$ (Aluminum ion)
Group 5A	X^{3-}	$X + 3\ e^{-} = X^{3-}$	**N** $^{3-}$ (nitride)
Group 6A	X^{2-}	$X + 2\ e^{-} = X^{2-}$	**O** $^{2-}$ (oxide)
Group 7A	X^{-}	$X + 1\ e^{-} = X^{-}$	**F** $^{-}$ (fluoride)

In the table (below), there are examples of some stable ions.
The ions of groups 1A (X^{+}), 2A (X^{2+}), 3A (X^{3+}), 5A (X^{3-}), 6A (X^{2-}), 7A (X^{-}), have an electron configuration like that of a noble gas, usually the closest to it.



Some stable ions do not have noble gas configurations. The transition metals often form ions without complete octet. These ions are all cations.
Sometimes, one element can form cations with more than one charge such as iron (Fe^{2+}, Fe^{3+}). The ion names include roman numerals to indicate charge.

Fe^{2+} is called Iron (II) ion. Fe^{3+} is called Iron (III) ion.
Cu^{+} is called copper (I) ion. Cu^{2+} is called Iron (II) ion

Ionic Bonds

Opposite charges attract each other. Therefore, cations (X^{n+}) and anions (X^{n-}) should attract each one another. The attraction is an electrostatic force.

Ionic bonds form between ions of opposite charge . In other words, Ionic compounds are made up of cations and anions with a whole-number ratio. Example: $A_{1, 2, 3, \ldots}$ $B_{1, 2, 3, \ldots}$

Salts are examples of ionic compounds. The ratio of cations to anions is always such that an ionic compound has no overall charge (0 charge, neutral).

When writing the ionic formula, compounds must have no overall charge.

Naming Ionic Compounds

The names of the ions are used to name an ionic compound. The name is made up to just two words: The name of the cation followed by the name of the anion.

Recall: The name of the cation is the same as the name of the parent element. Example: Na^+ : Sodium
The name of the anion is formed from the name of the parent element, but it ends in -ide. Example: Cl^- : Chloride. NaCl is (Na^+, Cl^-) is called sodium chloride.

Writing Ionic Formulas

Example1:

What is the formula of the ionic compound that can form between sodium (Na) and chlorine (Cl).

Follow the following steps when writing the formula of a binary ionic compound.

1) Write the symbol and charges for the cation and anion side by side. Refer to the table in page for the charges.

$$Na^+ \; Cl^-$$

2) We need to get a neutral compound (overall charge = 0). Positive charges = negative charges.

Na^+ has one positive charge (1+).

Cl^- has one negative charge (1-).

Positive charges = negative charges. Overall charge (1+) + (1-) = 0

The formula is writing as follows:

$$Na^+ \; Cl^-$$

Notice how the charges add up to 0: = (1+) + 1-) = 0

3) Write the final formula without the charges:

$$Na \; Cl$$

Name: Sodium Chloride

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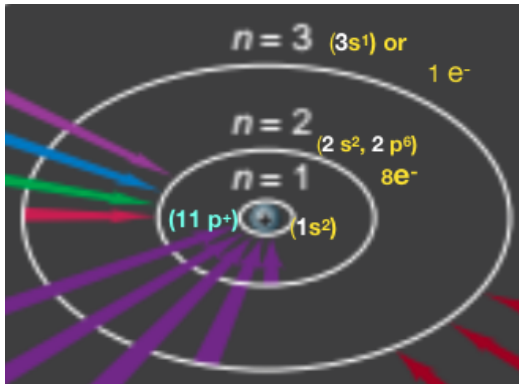
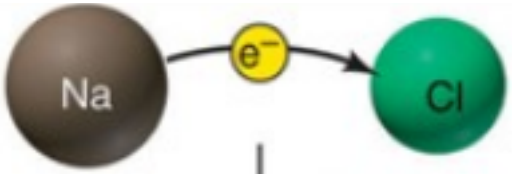
<td> 

Na</td>
<td> 
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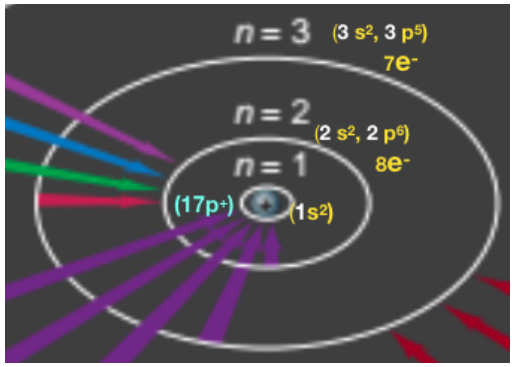
<td> 

Cl</td>
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<td>- 1 electron</td>
<td>  </td>
<td>+ 1 electron</td>
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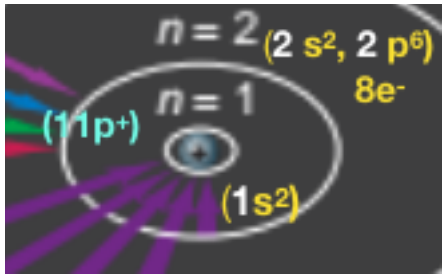
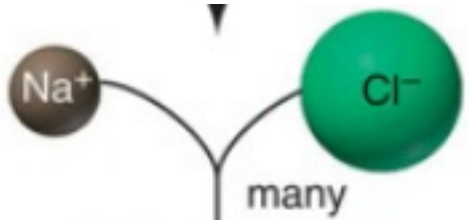
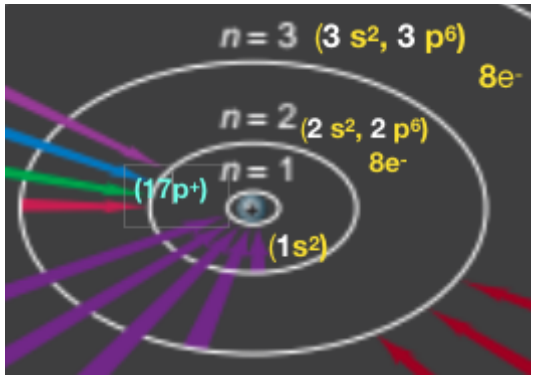
<td> 

Na⁺ (octet)</td>
<td> 

Electrostatic Attraction</td>
<td> 

Cl⁻ (octet)</td>
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<td>The ionic bond between Na⁺ and Cl⁻ is an electrostatic force that holds the atoms of elements together in the ionic compound NaCl (sodium chloride).</td>
<td> 
Ionic compound NaCl</td>
<td>NaCl
(Na⁺,Cl⁻)
sodium chloride</td>
</tr>
</table>

Example 2:

What is the formula of the ionic compound that can form between Aluminum (Al) and chlorine (Cl).

Follow the following steps when writing the formula of a binary ionic compound.

1) Write the symbol and charges for the cation and anion side by side. Refer to the table in page for the charges.

$$Al^{3+}\ Cl^{-}$$

2) We need to get a neutral compound (overall charge = 0). Positive charges = negative charges.

Al^{3+} has three positive charges (3+).

We need three negative charge (3-). Each Cl^- has one negative charge. So, we need $Cl^- + Cl^- + Cl^-$ or **3** Cl^- **.** The total negative charge is (**3** x 1-) = (**3 -**).

The formula is writing as follows:

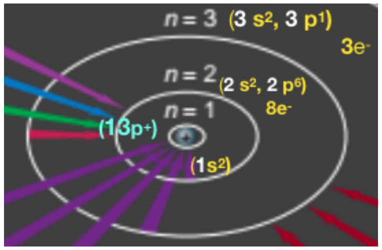
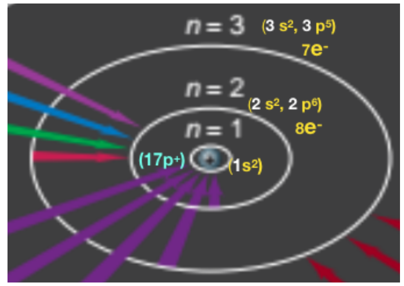
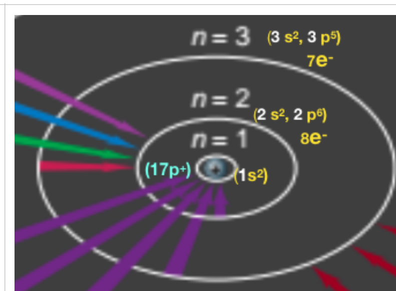
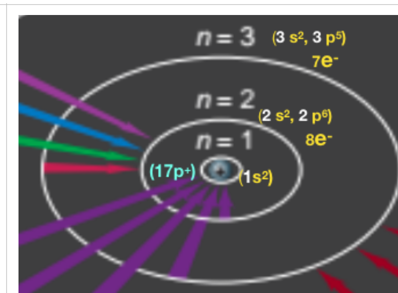
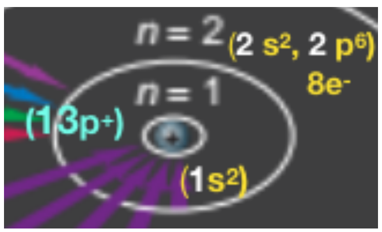
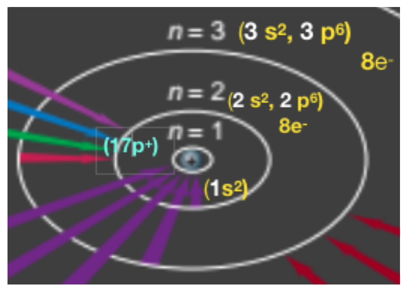
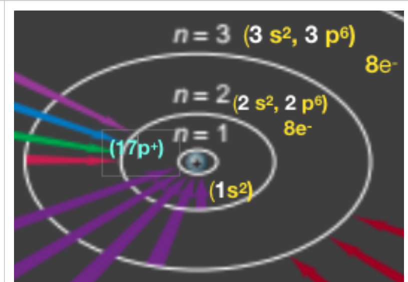
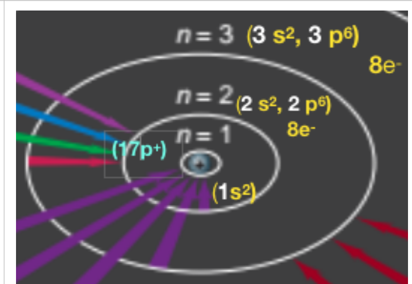
$$Al^{3+}\ Cl^{-}_{3}$$

Notice how the charges add up to 0: = (1 x 3+) + (**3** x 1**-**) = 0

3) Write the final formula without the charges:

$$Al\ Cl_3$$

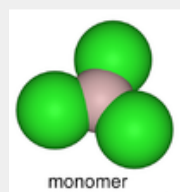
Name: Aluminum Chloride

 **Al**		 **Cl**	 **Cl**	 **Cl**
- 3 electrons	→	+ 1 electron	+ 1 electron	+ 1 electron
 **Al^{3+} (octet)**		 **Cl^- (octet)**	 **Cl^- (octet)**	 **Cl^- (octet)**

Electrostatic attraction between Al^{3+} and $3Cl^-$ to form the ionic compound $AlCl_3$

(Al^{3+}, 3 Cl^-)

Aluminum chloride



Example 3: What is the formula of the ionic compound that can form between Aluminum (Al) and oxygen (O).

1) Write the symbol and charges for the cation and anion side by side. Refer to the table in page for the charges.

$$Al^{3+}\ O^{2-}$$

2) We need to get a neutral compound (overall charge = 0).

Al^{3+} has three positive charges (3+). O^{2-} has two negative charges (2-).

We need to make the (+ charges) = (- charges)

Look for the lowest common multiple of the charges on the ions. The lowest common multiples for 3 and 2 is 6. The formula should indicate six positive charges (6+) and six negative charges (6-).

Al^{3+} + Al^{3+} gives 6+. So, we need **2** Al^{3+}

O^{2-} **+** O^{2-} **+** O^{2-} gives 6-. So, we need **3** O^{2-}

The formula will have : 2 Al^{3+} and 3 O^{2-}

$$Al^{3+}{}_{2}\ O^{2-}{}_{3}$$

notice how the positive charges (2 x 3+ = 6+) = negative charges (3 x 2- = 6-)

3) Write the final formula without the charges:

$$Al_2\ O_3$$

Name: Aluminum oxide

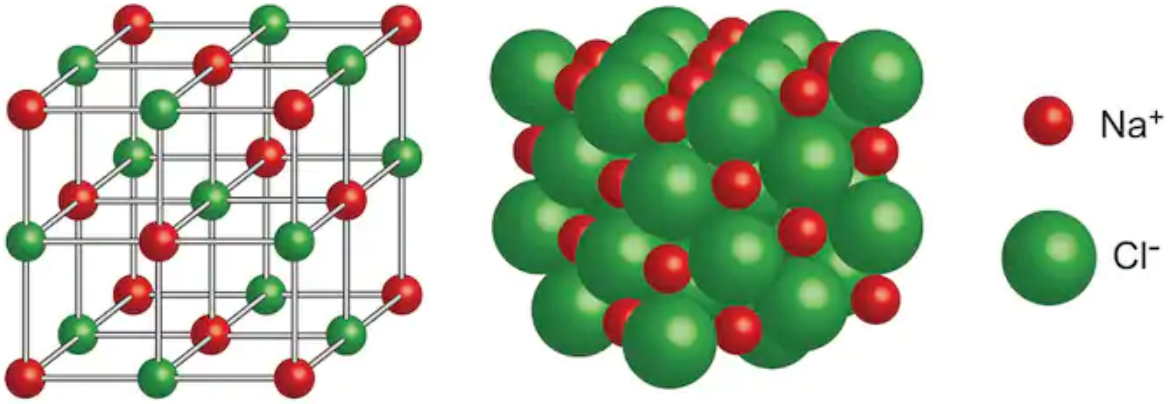
Properties of Ionic Compounds (Salts)

1. Ionic compounds form between ions of opposite charge.
2. Transferring electrons involves energy changes.

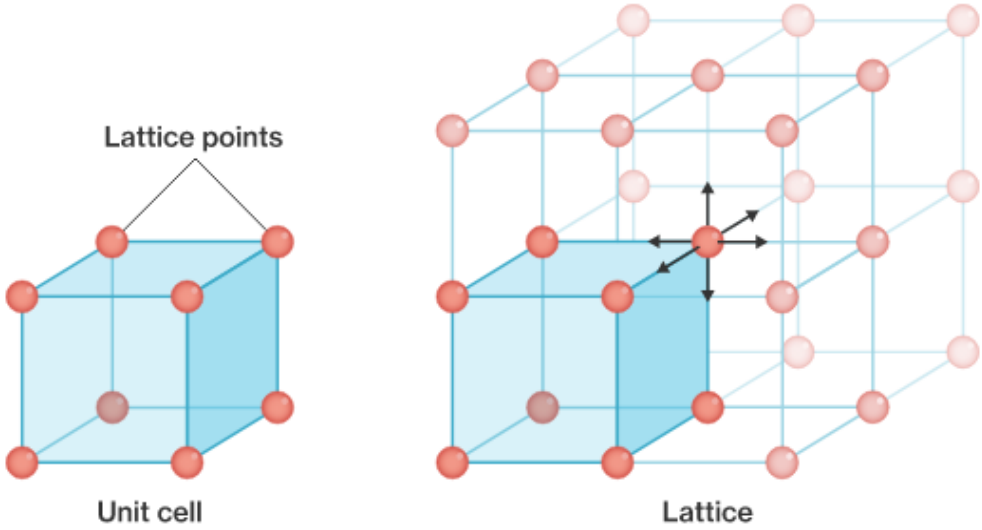
$$Na + \text{energy} \longrightarrow Na^+ + e^-$$
$$Cl + e^- \longrightarrow Cl^- + \text{energy}$$

3. Ionic compounds do not consist of molecules.
4. Ionic bonds are strong.
5. Ionic compounds have distinctive properties. They have high melting points at room temperature.
6. Liquid and dissolved salts conduct electric current.
7. Salts are hard and brittle. Hard means that the crystal is able to resist large for applied to it. Brittle means that when the applied force is too strong to resist, the crystals develops ad widespread fracture.
8. The ions in a salt crystal from repeating patterns called crystal lattice.
9. Crystal structure depends on the size and ratios of the ions.
10. Salts have ordered packing arrangements. The smallest repeating unit in a crystal lattice is called unit cell. It shows the three dimensional patter of the entire lattice.

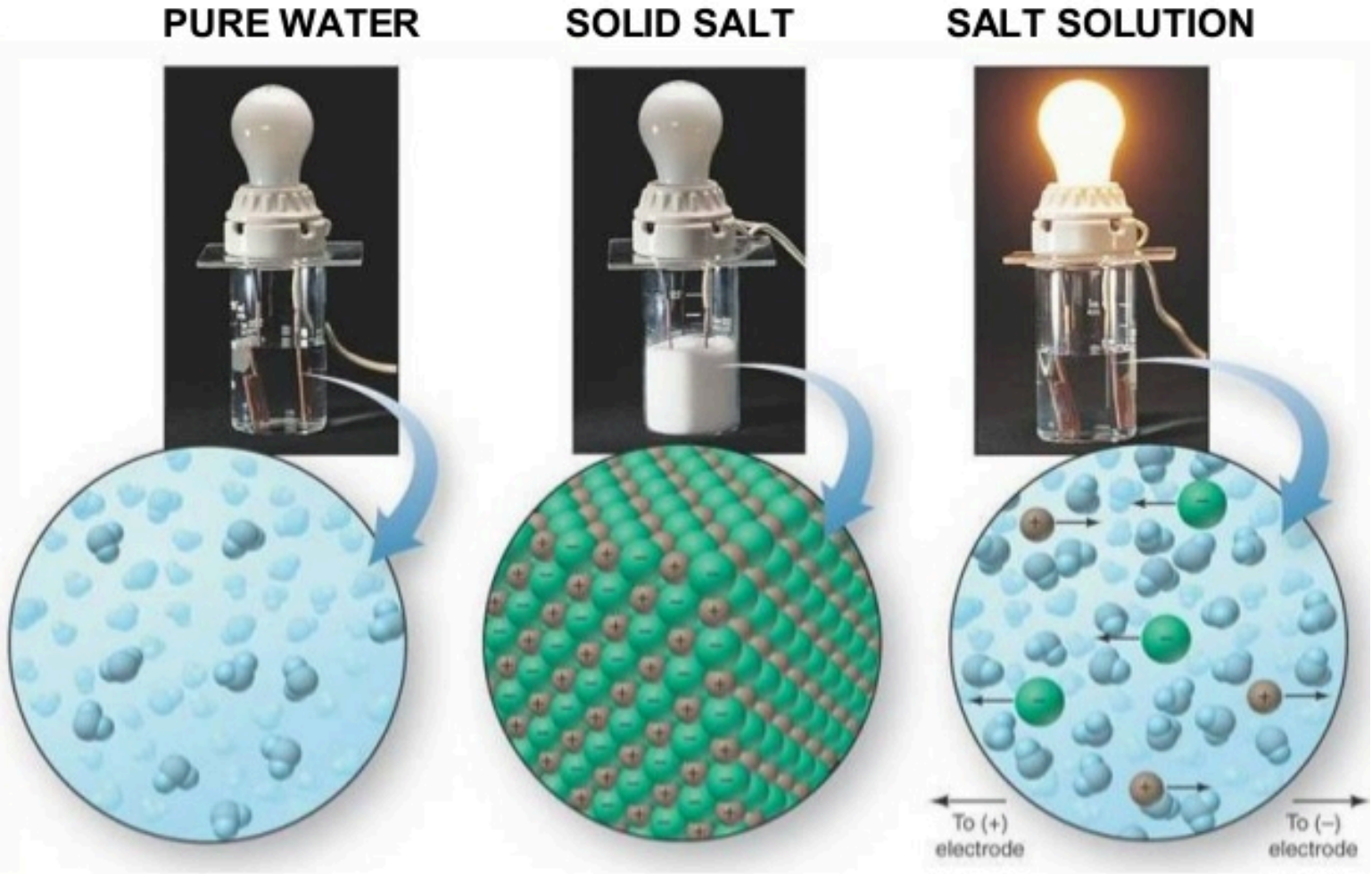
Lattice Structure of Crystals of the Salt NaCl



Simple Cubic Unit Cell



Dissolved Salts Conduct Electricity



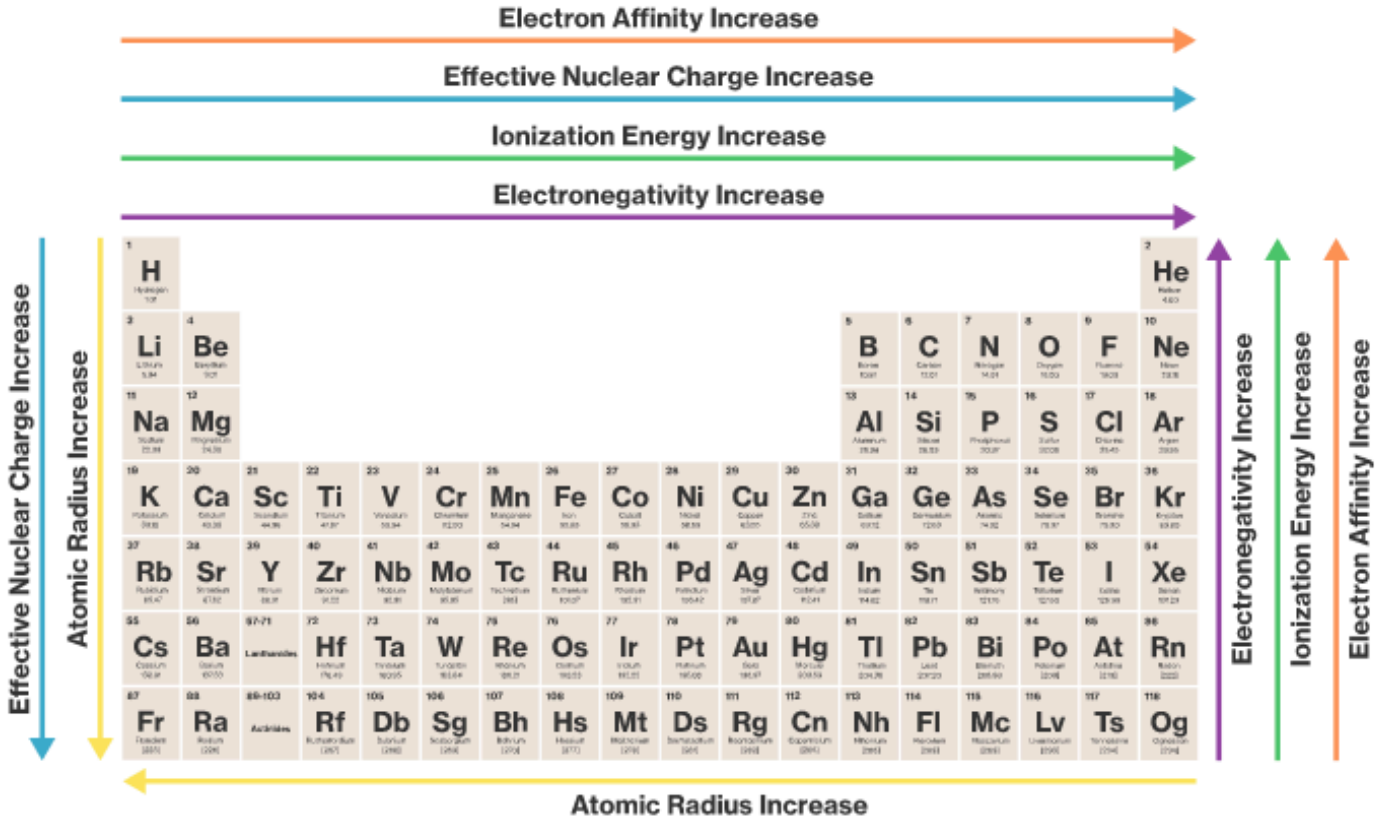
DISSOLVED ionic compounds also CONDUCT ELECTRICITY

Salts Have High Melting Points at Room Temperature.

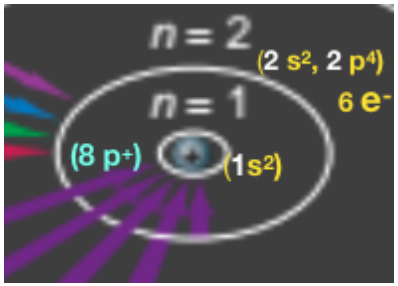
Ionic compound	Melting point (°C)
Iron chloride	677
Potassium chloride	770
Sodium chloride	801
Copper oxide	1446
Calcium oxide	2707

Electronegativity;

Electronegativity is a measure of the ability of an atom in a chemical compound to attract electrons and becomes an anion. It can be viewed as a tug of war to pull an electron. The atom with the higher electronegativity will pull on the electrons more strongly than the other atom will.
Electronegativity decreases as you move down a group.
Electronegativity increases as you move across a period.



Electronegativity Increases as You Move Across a Period.

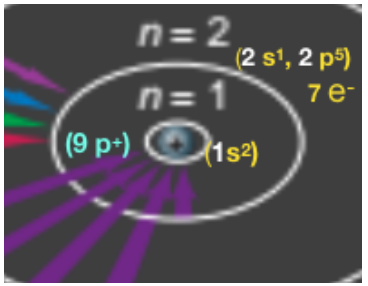


Oxygen (O)
Z = 8

1 electron

Which will pull the electron more to it, O or F?

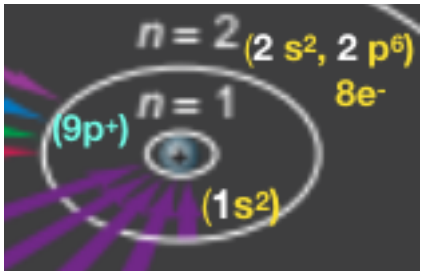
The atom with the higher electronegativity will pull on the electrons more strongly than the other atom will.



Fluorine (F)
Z = 9

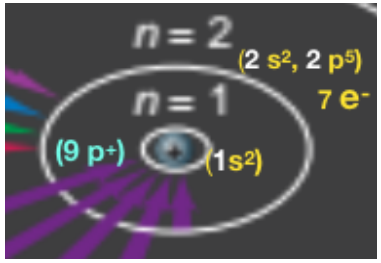
Both O and F have 2 energy levels. Both are in Period 2.
The nucleus of F is stronger because it has more protons.
F will pull the electron faster than O
F is more electronegative than O

F + 1 electron ———> F^-



F^-

Electronegativity Decreases as You Move Down a Group.

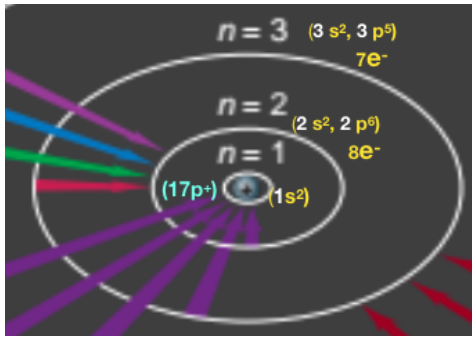


Fluorine (F)
Z = 9

1 electron

Which will pull the electron more to it, F or Cl?

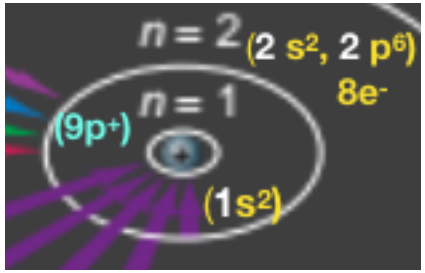
The atom with the higher electronegativity will pull on the electrons more strongly than the other atom will.



Chlorine (Cl)
Z = 17

Both F and Cl have 7 valence electrons. Both are in Group 7A or 17.
F has 2 energy levels (Period 2). Cl has 3 energy levels (Period 3)
The nucleus of F is closer to pull the electron from outside.
F is more electronegative than Cl

F + 1 electron ———> F^-



F^-