*Complete the worksheet using Class Notes, Text. Answers are provided at the end for guidance.*

**Ionic Bonding and Ionic Compounds**

\_\_\_\_\_\_\_ are electrically charged particles formed when atoms gain or lose \_\_\_\_\_\_\_\_\_\_. Once formed, ions have the same electron configurations as the \_\_\_\_\_\_\_\_\_ gases.

\_\_\_\_\_\_\_\_ (metal/non-metal) atoms form \_\_\_\_\_\_\_\_\_\_\_\_\_ (+ or -) ions, while \_\_\_\_\_\_\_\_\_ atoms form \_\_\_\_\_\_\_\_\_\_\_\_\_ ions. The strong \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ forces of attraction between \_\_\_\_\_\_\_\_\_\_\_\_ charged ions are called \_\_\_\_\_\_\_\_\_\_ bonds.

* Metal atoms \_\_\_\_\_\_\_ (lose/gain) the electron, or electrons, in their \_\_\_\_\_\_\_\_\_ energy level and become positively charged \_\_\_\_\_\_\_.
* Non-metal atoms \_\_\_\_\_\_\_ an electron, or electrons, from another atom to become negatively charged \_\_\_\_\_\_\_.

|  |  |
| --- | --- |
| Draw the charged sodium & aluminum ions | Draw the charged oxide & chloride ions |
|  |  |

There is a quick way to work out what the charge on an ion should be:

* The number of charges on an ion formed by a metal is equal to the group number of the metal
* The number of charges on an ion formed by a non-metal is equal to the group number minus eight

FILL IN the chart below:

|  | **Group 1** | **Group 2** | **Group 3** | **Group 4** | **Group 5** | **Group 6** | **Group 7** | **Group 0** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Example element** |  |  |  | C |  |  |  |  |
| **Charge** |  |  |  | ±4 |  |  |  |  |
| **Symbol of ion** |  |  |  | C+4 or C-4 |  |  |  |  |

**Metals**: Make Lewis Structure (electron dot diagram) for the atoms. Show valence of the ions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Lithium Atom | Lithium Ion |  | Sodium Atom | Sodium Ion |
|  |  |  |  |  |
|  |  |  |  |  |
| Magnesium Atom | Magnesium Ion |  | Calcium Atom | Calcium Ion |
|  |  |  |  |  |

**Lithium** is in Group \_\_\_\_. It has \_\_\_\_ electron in its highest energy level. When this electron is \_\_\_\_\_\_\_ (lost/gained), a lithium \_\_\_\_\_\_ (cation/anion) (Li+) is formed.

**Sodium** is also in Group \_\_\_. It has \_\_\_\_ electron in its highest energy level. When this electron is \_\_\_\_\_\_\_, a sodium \_\_\_\_\_\_\_\_ (Na+) is formed. Note that a sodium ion has the same electron configuration as a \_\_\_\_\_\_\_\_ atom (noble gas, group \_\_\_\_). But be careful: a sodium ion is not a neon atom. This is because the nucleus of a sodium ion has \_\_\_\_ protons, but the nucleus of a neon atom has \_\_\_\_.

**Magnesium** is in Group \_\_\_. It has \_\_\_\_\_\_ electrons in its highest energy level. When these electrons are \_\_\_\_\_\_, a magnesium \_\_\_\_\_\_\_ (Mg2+) is formed. A magnesium ion has the same electron configuration structure as a \_\_\_\_\_\_\_\_ atom (\_\_\_\_\_\_\_\_ gas, group VIIIA).

**Calcium** is also in Group \_\_\_. It has \_\_\_\_\_ electrons in its highest energy level. When these electrons are \_\_\_\_\_\_\_, a calcium \_\_\_\_\_\_\_ Ca2+ is formed. A calcium ion has the same electronic structure as an \_\_\_\_\_\_\_\_\_\_ atom (Ar).

**NON-Metals**: Make Lewis Structures (electron dot diagrams) for the atoms. Show the valence of the ions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Fluorine Atom | Fluoride Ion |  | Neon Atom |  |
|  |  |  |  | Notice Neon has no charge |
|  |  |  |  |  |
| Chlorine Atom | Chloride Ion |  | Oxygen Atom | Oxide Ion |
|  |  |  |  |  |

**Fluorine** is in Group \_\_\_. It has \_\_\_\_ electrons in its highest energy level. It \_\_\_\_\_\_\_ (gains/loses) an electron from another atom in reactions, forming a fluoride \_\_\_\_\_\_\_, F-. Note that the atom is called fluorine, but the ion is called \_\_\_\_\_\_\_\_\_\_. Note that a fluoride ion has the same electron configuration as a \_\_\_\_\_\_\_ atom (noble gas, group \_\_\_\_\_\_). Once again, a fluoride ion is not a neon atom, because the nucleus of a fluoride ion has \_\_\_\_protons, and the nucleus of a neon atom has \_\_\_\_.

**Chlorine** is in Group \_\_\_. It has \_\_\_\_\_\_\_ electrons in its highest energy level. It \_\_\_\_\_\_\_\_ an electron from another atom in reactions, forming a chloride \_\_\_\_\_\_, Cl-.

**Oxygen** is in Group \_\_\_. It has \_\_\_\_\_ electrons in its highest energy level. It \_\_\_\_\_\_ two electrons from one or two other atoms in reactions, forming an oxide \_\_\_\_\_, O2-.

* When metals react with non-metals, electrons are \_\_\_\_\_\_\_\_\_\_ (transferred/shared) from the \_\_\_\_\_\_\_ atoms to the \_\_\_\_\_\_ atoms, forming \_\_\_\_\_. The resulting compound is called an \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_. In each of these reactions, the metal atoms give electrons to the non-metal atoms, so that the metal atoms become \_\_\_\_\_\_\_\_\_\_\_\_\_\_ cations and the non-metal atoms become \_\_\_\_\_\_\_\_\_\_\_\_\_\_ anions. There is a strong \_\_\_\_\_\_\_\_\_\_\_\_\_\_ force of attraction between these \_\_\_\_\_\_\_\_\_\_\_\_-charged ions, called an **\_\_\_\_\_\_\_\_ bond**.

Draw the Lewis Structures before and after bonding:

|  |  |  |
| --- | --- | --- |
| Ionic Compound | Before | After |
| Sodium chloride  NaCl |  |  |
| Magnesium Oxide  MgO |  |  |
| Calcium Chloride  CaCl2 |  | |

There are many ionic bonds in an ionic compound such as sodium chloride, arranged in giant \_\_\_\_\_\_\_\_\_\_ structures. Ionic compounds have \_\_\_\_\_\_\_ (high/low) melting and boiling points.

When elements that make up compounds or molecules have an END (\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_) greater than **\_\_\_\_\_**, we say they are **\_\_\_\_\_\_\_\_\_\_**.

Ionic \_\_\_\_\_\_\_ do NOT conduct electricity (no free moving \_\_\_\_\_).

They do conduct current when melted (\_\_\_\_\_\_ state), vaporized (gaseous state), or \_\_\_\_\_\_\_ in water because ions can flow fleely.

Determine whether each combination results in an ionic compound (Reference Table 1, Chart K).

aluminum and oxygen END =

calcium and aluminum END =

fluorine and oxygen END =

lithium and fluorine END =

carbon and oxygen END =

sodium and fluorine END =

Metals tend to have (low/high) ionization energies because they tend to \_\_\_\_ electrons.

Nonmetals tend to have \_\_\_\_ electronegativities because they tend to \_\_\_\_ electrons.

Which of the following apply to ionic compounds?

[ ] cleavage along a definite plane

[ ] high melting points

[ ] conduct electricity all the time

[ ] electrons are transferred between atoms

“\_\_\_\_\_\_\_\_\_” is the ability to split the crystal lattice along a definite plane, thus, fragmenting the crystal lattice.

\_\_\_\_\_\_\_\_\_ bonds are the forces of attraction between the free-floating \_\_\_\_\_\_\_\_ electrons and the positively charged metal ions. These bonds hold metals together.

Metallic bonding results from the \_\_\_\_\_ of valence electrons among any of the metal atoms. “\_\_\_\_\_\_\_\_\_\_\_\_” electrons act like glue. Electron \_\_\_\_\_ model: electrons flow easily between atoms as in a “sea” of electrons in which nuclei “float”

Draw the electron sea model:

Name and define metallic properties that result from this model:

Homogeneous mixtures (solutions) of two or more metals are called \_\_\_\_\_\_\_\_. They are important because their properties are often \_\_\_\_\_\_\_ to those of their component elements.

ANSWERS

**Ionic Bonding and Ionic Compounds**

**IONS** are electrically charged particles formed when atoms gain or lose **ELECTRONS.** Once formed, ions have the same electron configurations as the **NOBLE** gases.

**METAL** atoms form **POSITIVE** ions, while **NON**-metal atoms form **NEGATIVE** ions. The strong [**ELECTROSTATIC**](http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/atomic/ionicrev1.shtml) forces of attraction between **OPPOSITELY** charged ions are called **IONIC** bonds.

* Metal atoms **LOSE** the electron, or electrons, in their **HIGHEST** energy level and become positively charged **CATIONS.**
* Non-metal atoms **GAIN** an electron, or electrons, from another atom to become negatively charged **ANIONS**.

|  |  |
| --- | --- |
| Draw the charged sodium & aluminum ions  Na+ Al+3 | Draw the charged oxide & chloride ions  O-2 Cl-1 |

There is a quick way to work out what the charge on an ion should be:

* The number of charges on an ion formed by a metal is equal to the group number of the metal
* The number of charges on an ion formed by a non-metal is equal to the group number minus eight

FILL IN the chart below:

|  | **Group 1** | **Group 2** | **Group 3** | **Group 4** | **Group 5** | **Group 6** | **Group 7** | **Group 0** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Example element** | Na | Mg | Al | C | N | O | Cl | He |
| **Charge** | +1 | +2 | +3 | ±4 | -3 | -2 | -1 | 0 |
| **Symbol of ion** | Na+1 | Mg+2 | Al+3 | C+4 or C-4 | N-3 | O-3 | Cl-1 | He0 |

Make Lewis Structure (electron dot diagram) for the atoms. Show valence of the ions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Lithium Atom | Lithium Ion |  | Sodium Atom | Sodium Ion |
|  | +    Li+ |  |  | +    Na+ |
|  |  |  |  |  |
| Magnesium Atom | Magnesium Ion |  | Calcium Atom | Calcium Ion |
|  | +2    Mg+2 |  |  | +2    Ca+ |

**Lithium** is in Group **IA.** It has **1** electronin its highest energy level. When this electron is **lost**, a lithium **cation** (Li+) is formed.

**Sodium** is also in Group **IA**. It has **1** electron in its highest energy level. When this electron is **LOST**, a sodium **CATION** (Na+) is formed. Note that a sodium ion has the same electron configuration as a **NEON2** atom (noble gas, group VIIIA). But be careful: a sodium ion is not a neon atom. This is because the nucleus of a sodium ion has **11** protons, but the nucleus of a neon atom has **10**.

**Magnesium** is in Group **IIA**. It has **2** electrons in its highest energy level. When these electrons are **LOST**, a magnesium **CATION** (Mg2+) is formed. A magnesium ion has the same electron configuration as a **NEON** atom (**NOBLE** gas, group VIIIA).

**Calcium** is also in Group **IIA**. It has **2** electrons in its highest energy level. When these electrons are **LOST**, a calcium **CATION** (Ca2+) is formed. A calcium ion has the same electron configuration as an **ARGON** atom (noble gas, group VIIIA).

**NON-Metals**: Make Lewis Structures (electron dot diagrams) for the atoms. Show the valence of the ions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Fluorine Atom F | Fluoride Ion F- |  | Neon Atom Ne |  |
|  | F- |  |  | Notice Neon has no charge |
|  |  |  |  |  |
| Chlorine Atom Cl | Chloride Ion Cl- |  | Oxygen Atom O | Oxide Ion O-2 |
|  | Cl- |  |  | O-2 |

**Fluorine** is in Group **VIIA**. It has **7** electrons in its highest energy level. It **GAINS** an electron from another atom in reactions, forming a fluoride **ANION**, F-. Note that the atom is called fluorine, but the ion is called **FLUORIDE**. Note that a fluoride ion has the same electronic structure as a **NEION** atom (noble gas, group **VIIIA**). Once again, a fluoride ion is not a neon atom, because the nucleus of a fluoride ion has **9** protons, and the nucleus of a neon atom has **10**.

**Chlorine** is in Group **VIIA**. It has **7** electrons in its highest energy level. It **GAINS** an electron from another atom in reactions, forming a chloride **ANION**, Cl-.

**Oxygen** is in Group **VIA**. It has **6** electrons in its highest energy level. It **GAINS** two electrons from one or two other atoms in reactions, forming an oxide **ANION**, O2-.

* When metals react with non-metals, electrons are **TRANSFERRED** from the **METAL** atoms to the **NON-METAL** atoms, forming **IONS**. The resulting compound is called an **IONIC COMPOUND**. In each of these reactions, the metal atoms give electrons to the non-metal atoms, so that the metal atoms become **POSITIVE** cations and the non-metal atoms become **NEGATIVE** anions. There is a strong **ELECTROSTATIC** force of attraction between these **OPPOSITELY**-charged ions, called an **IONIC bond**.

Draw the Lewis Structures before and after bonding:

|  |  |  |
| --- | --- | --- |
| Ionic Compound | Before | After |
| Sodium chloride  NaCl |  | **NaCl** |
| Magnesium Oxide  MgO |  |  |
| Calcium Chloride  CaCl2 | **CaCl2** | |

There are many ionic bonds in an ionic compound such as sodium chloride, arranged in giant ­­­­**LATTICE** structures. Ionic compounds have **HIGH** melting and boiling points.

When elements that make up compounds or molecules have an END (**ElectroNegativity** **Difference**) greater than **1.7**, we say they are **IONIC**.

Ionic **SOLIDS** do NOT conduct electricity (no free moving **IONS**).

They do conduct current when melted (**LIQUID** state), vaporized (gaseous state), or **DISSOLVED** in water because ions can flow fleely.

Determine whether each combination results in an ionic compound (Reference Table 1, Chart K).

aluminum and oxygen END = 3.5 - 1.5 = **2.0 … IONIC**

calcium and aluminum END = 1.5 - 1.0 = 0.5 (two metals will NOT form an ionic compound)

fluorine and oxygen END = 4.0 – 3.5 = 0.5 (two non-metals will NOT form ionic compounds)

lithium and fluorine END = 4.0 - 1.0 = **3.0 … IONIC**

carbon and oxygen END = 3.5 – 2.6 = 0.9

sodium and fluorine END = 4.0 – 0.9 = **3.1 … IONIC**

Metals tend to have (**LOW**) ionization energies because they tend to **LOSE** electrons. Nonmetals tend to have (**HIGH**) electronegativities because they tend to **GAIN** electrons.

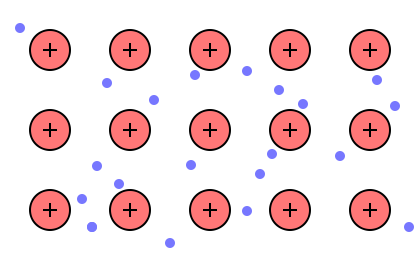
Which of the following apply to ionic compounds?

* cleavage along a definite plane
* high melting points
* electrons are transferred between atoms

“**CLEAVAGE**” is the ability to split the crystal lattice along a definite plane, thus, fragmenting the crystal lattice.

**METALLIC BONDS** are the forces of attraction between the free-floating **VALENCE** electrons and the positively charged metal ions. These bonds hold metals together.

Metallic bonding results from the **SHARING** of valence electrons among any of the metal atoms. “**DELOCALIZED**” electrons act like glue. **ELECTRON SEA MODEL:** electrons flow easily between atoms as in a “sea” of electrons in which nuclei “float”



Draw the electron sea model 🡪

Name and define metallic properties that result from this model:

Ductile — can be drawn into wires.

Malleable — hammered or pressed into shapes.

Good Conductors of heat and electricity.

Homogeneous mixtures (solutions) of two or more metals are called **alloys**. They are important because their properties are often **SUPERIOR** to those of their component elements.