

Nomenclature & Formula Writing 1

Ions & Valence Electrons

INFORMATION

Definition of Ions

Recall that the **proton** is a particle with a positive charge, and the **electron** is a particle with a negative charge. A proton is said to have a **relative charge** of +1, and an electron is said to have a relative charge of -1.

Normally, individual **free state** (unbounded) atoms have a number of electrons equal to the number of protons in their nuclei (recall that the number of protons is the atomic number, Z). Thus, in a carbon atom, for example, which has an atomic number of 6, there is a total charge in the nucleus (a **nuclear charge**) of +6. The total charge of all of its electrons is -6. The carbon atom is neutral because the total charge of its protons is balanced by the total charge of its electrons.

However, any time an atom has a number of electrons that *differs* from the number of protons, the atom is said to be an **ion**. The definition of an ion is any atom that possesses a net charge. *Forming an ion requires an input of energy*, whether the ion is positive or negative.

The purpose of forming an ion is to allow the atom to participate in an **ionic bond**.

An ion is any atom that possesses a net charge.

An atom with a positive **net charge** is called a **cation** (pronounced cat-ion), and an atom with a negative net charge is called an **anion** (pronounced an-ion). Ions are referred to using the word cation or anion following the name of the ion – for example, *magnesium cation* or *chloride anion*. Generally speaking, cations donate (lose) electrons, and anions accept (gain) electrons.

Since protons cannot be removed from the nucleus of an atom, charge in an atom is created by manipulating (that is, adding or removing) electrons. If an atom gains an electron (an electron is added), the atom gains an additional -1 charge, since the total number of electrons exceeds the number of protons by 1. If the electron loses an electron (an electron is removed), the atoms gains an additional +1 charge, since the number of protons exceeds the number of electrons by 1. Keep in mind that the signs make this seem counter-intuitive – *adding* an electron results in a *more negative* charge, and *removing* an electron results in a *more positive* charge. Changes in charge as the result of the gain or loss of multiple electrons are cumulative.

Writing Symbols for Ions

An ion is written simply by writing the element's symbol, followed by the charge value as a *superscript*. For example, a sodium cation with a charge of +1 would be written as Na^{+1} , and a nitride (nitrogen) anion with a charge of -3 would be written as N^{-3} .

Representative Elements

The **representative elements** on the periodic table are those elements that fall into the first two tall columns on the far left of the periodic table, and the five tall column s on the far right, excepting the noble gases. The **transition metals** in the center are not part of the representative elements.

Valence Electrons

Every atom has a specific number of **valence electrons**. Valence electrons are located in the **valence shell** of an atom. The valence shell is the outermost “layer” of the atom, located in the highest energy level. The valence electrons are the most important in the atom – they are the electrons that participate in

bonding (combinations of multiple atoms to form new compounds) with other atoms. The number of valence electrons in an atom determines the proportions in which it will bond with other atoms, or, as in the case of the noble gases, whether they will form bonds at all.

Valence electrons are important when an atom bonds with other atoms to form compounds.

The design of the periodic table includes many patterns, or **trends**, that indicate the properties of the elements in the table. One of the most basic trends in the periodic table deals with indicating the number of valence electrons in a particular atom.

To determine the number of valence electrons in a representative element, one simply needs to follow these steps:

1. Locate the element in the **periodic table**.
2. Starting with the first column of representative elements on the left, count over until you reach the **group** (column) containing the element of interest. *Don't forget to skip over the transition elements.*
3. The number counted represents the number of valence electrons in the atom.

Carbon is found in the fourth column from the left. This gives carbon 4 valence electrons. Chlorine, in the seventh column, has 7 valence electrons.

The exception to this rule is helium – due to the configuration of its atomic orbitals¹ helium has only 2 valence electrons, not 8 as its group would indicate.



Key Questions:

1. What is the charge of a neutral atom when it:
 - a. Loses 2 electrons?
 - b. Gains 1 electron?
 - c. Gains 4 electrons?
 - d. Loses 5 electrons?
2. What is the fewest number of valence electrons an atom of a representative element can have? What is the greatest number of valence electrons an atom of a representative element can have?
3. Is it possible for an atom to have zero valence electrons at any time? Explain.
4. Why would non-valence electrons (that is, electrons in shells other than the valence shells) be much less likely to participate in a bond?
5. In grammatically correct English, write a few simple rules for determining all of the possible charges for any given representative element (assuming it is theoretically possible for any atom to have any charge). When you finish, apply those rules to a carbon atom and determine all of its theoretically possible charges.

¹ See the *Electronic Structure of the Atom* series for more information about atomic orbitals