

Quantifying Chemical Compounds Script

In this video we will begin to piece together the puzzle that describes how atoms interact with each other. This video gives an outline of how bonded atoms are quantified, covers properties of atoms, and touches on advanced periodic trends.

Two laws were formed based on observations of scientists conducting research in the late eighteenth and early nineteenth century. These laws predate atomic theory, and were instrumental to scientists in determining that matter is composed of atoms. A compound is two or more bonded atoms of different types bonded together.

The law of multiple proportions proposed by the French chemist Joseph Proust states that, elements combine in different ways to form substances whose mass ratios are small whole number multiples of each other. For example, the mass of carbon that combines with the mass of oxygen to form carbon monoxide, will always have the mass ratio of one carbon to one oxygen. Similarly, the mass of carbon that combines with the mass of oxygen to form carbon dioxide, will always have the mass ratio of one carbon to two oxygen.

The second law, put forth by John Dalton, is the law of definite proportions. It states that all samples of a pure chemical substance will always contain the same proportion of elements by mass, regardless of the sample's origin. By mass, carbon dioxide is seventy-three percent oxygen and twenty-seven percent carbon. The law of definite proportions implies that irrespective to production, either by combustion or respiration, all carbon dioxide is chemically the same in every location.

How can we practically apply these laws to quantifying chemical compounds? The answer is to revisit the mole. We know that one mole is equal to 6.022×10^{23} objects, and one mole of any element is equal to its molar mass, but what about compounds? The molar masses of each element are used to determine the molar mass of a compound, so, one mole of any compound is equal to the sum of the molar masses of all elements in that compound. One mole of carbon has a molar mass of 12.01g/mol, and one mole of oxygen has a molar mass of 16.00 g/mol. We simply add together the molar mass of each element in the compound. Carbon dioxide has one carbon and two oxygens, so this means that one mole of carbon dioxide has a molar mass of 44.01 g/mol.

We need to be aware that numbers of moles is a direct comparison of the relative number of atoms or molecules. The mole is used extensively in chemical calculations and experiments because numbers of atoms can be compared. Comparing relative numbers of atoms has a specific notation. We use an empirical or molecular formula to describe the relative number of atoms in each compound.

An empirical formula is the lowest whole integer numbers representing an atomic ratio of a molecule using a chemical description. This means to calculate the empirical formula of a compound, find the smallest whole number molar ratio between the constituent atoms, and write the ratio using the chemical symbols of the atoms. The empirical formula for hydrogen peroxide is HO.

A molecular formula is the chemical description of the actual complete molecule. The molecular formula for hydrogen peroxide is H_2O_2 . Given the molar mass of a compound and its empirical formula, the molecular formula can be determined by finding the whole number multiplier that will yield the compound's given molar mass. Some compounds, such as water, have empirical and molecular formulas that are the same. The molecular and empirical formula of water is H_2O .

The periodic table is organized to aid chemists in determining helpful information about elements, such as: atomic radius, electronegativity, and ionization energy. Learning this information, and recognizing the periodic trends helps us to understand why elements combine in certain ways and have certain properties.

Electronegativity is the ability of a bonded atom to attract electrons. On the periodic table electronegativity decreases moving down a column, and electronegativity increases moving across a row.

Electronegativity differences (ΔEN) for bonded atoms can be calculated by subtracting the least electronegative atom from the atom with the highest electronegativity. The electronegativity of an atom can be found: on some periodic tables, in chemistry textbooks, or in chemical constant databases. The difference in electronegativity dictates which type of bond is present in the compound. The electronegativity difference for hydrochloric acid is determined by subtracting the electronegativity value of the hydrogen atom, 2.1, from the electronegativity of a chlorine atom, 3.0. This gives hydrochloric acid an electronegativity difference of 0.9. We will learn later how this difference correlates to bond types.

The next property we are going to discuss is atomic radius. The atomic radius is the average bonding radius of an element. It is determined from averaging measurements of many compounds and molecules. The bond length of two bonded atoms is determined by adding their atomic radii. Similar to the electronegativity of an atom the atomic radius can be located: on periodic tables, in chemistry textbooks or in chemical constant databases. Moving down a column on the periodic table the principle quantum number, (n), of the outermost electrons increases. Orbitals are larger, therefore, the atomic radii are larger. Moving across a row on the periodic table the electrons in the outermost shell feel the charge from the nucleus more strongly. The electrons are closer to the nucleus, so orbitals are smaller, therefore, the radii are smaller.

The atomic radius of ions changes with the loss or gain of electrons. A cation will have a smaller radius than the neutral atom. Fewer electrons result in a smaller electron cloud, and a correspondingly smaller ionic radius. An anion will have a larger radius than the neutral atom. More electrons result in a larger electron cloud, and a correspondingly larger ionic radius.

The final atomic property that we need to be aware of is ionization energy. Ionization energy is the amount of energy required to remove one electron from an atom, or ion, in a gaseous state. Moving down a column on the periodic table the principle quantum number (n) of the outermost electrons increase, orbitals are larger, therefore it takes less energy to remove an electron because they are farther from the nucleus. Moving

across a row the electrons in the outermost shell feel the charge from the nucleus more strongly, orbitals are smaller, therefore it takes more energy to remove an electron because they are closer to the nucleus.

We have now covered the beginning concepts of how atoms combine to form compounds. You should be able to define: compound, empirical formula, and molecular formula, and be comfortable explaining the law of multiple proportions and the law of definite proportions. You should be able to calculate the molar mass, electronegativity difference and bond length of a compound. You should be able to define electronegativity, atomic radius, ionization energy and identify the periodic trends that relate to these terms. This section contains detailed example problems with solutions that you should work through before moving on to the next section.