Simple and complex substances
What is chemistry?

You come to high school and you want to form your opinion about true real science after middle school. We will try to present to you in chemistry class today the new concepts the chemists have now about simple and complex substances.

People have a notion of a kind of a substance from which no new substances can be obtained if the original substance becomes in isolation from other substances. The substance of such kind is called an element.

Let us consider gold as an example. If we take gold and isolate it from its surroundings, no matter what we do to it, it is still gold. We can heat it, hit it with a hammer, melt it, run electric current through it - it is still gold, it does not become any other kind of substance or no two or more physically different other substances can be obtained from it. Then we arrive at a correct conclusion that the physical processes do not turn gold into anything else if it is not in contact with other substances.

Let us consider magnesium. It is a simple substance, too.

Please, put on your safety glasses. I will take a small piece of magnesium with the tongs and ignite it with a match.

You observe a bright flame and a magnesium burning, white powder appears.

If we do not isolate magnesium and heat it up in the air in the flame, magnesium turns into a white powder, which is magnesium oxide. We observe then the phenomenon that magnesium vanishes and in place of it some new substance is being created. The new substance has different physical properties from magnesium, which was the original substance. Magnesium oxide has different density, color, ductility, i.e. it does no longer have plasticity like the metal.

We also cannot obtain magnesium back from magnesium oxide by just performing physical operations on magnesium oxide such as dissolving it in a solvent and in crystallization process and we are unable to perform physical separation of any kind on magnesium oxide to obtain magnesium from it. Magnesium oxide is homogenous in the sense that we cannot separate magnesium from it like we could separate physically rocks or sand from water. We see that when magnesium was exposed to air in a flame, some nonphysical changes occurred because we no longer can obtain magnesium back from magnesium oxide in physical processes.

Let us consider zinc, a simple substance, and an element and let us submerge a piece of zinc in sulfuric acid. We get a situation when zinc, a simple substance, an element interacts with a complex substance, the sulfuric acid. Zinc vanishes, some gas bubbles appear and from the solution we can crystallize a white powder zinc sulfate $ZnSO_4$ which is different than zinc and different than the sulfuric acid. We no longer can obtain zinc from it, neither sulfuric acid from it in a physical process like crystallization.

Let us consider alcohol in wine. Alcohol is not a simple substance, not an element. Some bacteria may turn alcohol into vinegar in a process called fermentation. Louis Pasteur has proven that. Vinegar no longer can be turned into alcohol in any physical process. A new complex substance was formed: vinegar from alcohol, which is called by chemists acetic acid.

We have two kinds of substances then:

* Simple substance which when in isolation from other substances does not undergo any changes in which two or more other substances are formed

* Complex substance that is formed from simple substances, from simple substances and other complex substances, or from other complex substances

The processes of nonphysical changes leading to formation of substances simple or complex are called chemical reactions.

Chemistry is the science the subject of which is the study of the chemical reactions.

In chemistry simple substances are called elements and complex substances are called chemical compounds.

Some substances occur naturally in non-living organisms. The chemistry of such substances (what means the study of chemical reactions of such substances) is called inorganic chemistry.

For example there is iron and rust, and iron ore in the ground. The chemical substances such as elemental iron, and chemical substances such as rust which mainly contains iron oxide Fe_2O_3 or iron ore Fe_3O_4 in fact are not present in any plant or animal. There are situations then when elements are present in typically inorganic compounds and the reactions of these compounds are being the subject of studies in inorganic chemistry.

Some substances are present naturally only in plants and animals or are produced by living cells and are called organic compounds. The chemistry of such substances (what means the study of chemical reactions of such substances) is called organic chemistry. It is known to chemists that organic compounds typically always contain carbon. Other elements like hydrogen, oxygen, nitrogen, and sulfur also can be present. Organic chemistry today has got extended to studies of derivatives of substances, which naturally occurred in living cells however do not occur in living organisms. Example: chloromethane, dichloromethane, chloroform, tetrachloromethane are derivatives of methane which is produced from organic matter by methanogens microorganisms however chlorinated derivatives of methane, which are not naturally produced in living organisms are also being considered organic compounds.

So we see that other elements typically being studied in inorganic chemistry, like chlorine can also be present in organic compounds, which no longer occur in living organisms. However we can find also an example of an element typically being studied in inorganic chemistry that is present in living organisms, too.
Iron is naturally present in human body in a chemical organic compound called hemoglobin, which is responsible for transporting oxygen to living tissues. Chemistry of iron is typically considered as inorganic chemistry.

Sometimes we would like to have a general look at elements, inorganic and organic compounds and investigate some typical and even common chemical properties of those substances. The typical chemical properties of elements and organic and inorganic compounds are the subject of studies in general chemistry.

Sometimes we start asking questions about physical properties of chemical elements and chemical compounds. The studies of physical properties of chemical substances are the subject of physical chemistry.

At times we want to ask questions about the elemental composition of chemical compounds, or about a chemical composition of a mixture of substances. The studies leading to determination of elemental composition of substances or chemical compositions of mixtures of substances are the subject of analytical chemistry.

With the development of physics and especially quantum mechanics in the beginning of the 20-th century scientists started to understand physical laws governing chemical reactions and properties of chemical elements and chemical compounds. The appropriate theories have been constructed and mathematical computations of the properties of chemical compounds and chemical reactions became possible. The branch of chemistry, which enables theoretical studies of chemical reactions and of the properties of chemical elements and compounds, is called theoretical chemistry.

Studies leading to use of computers in theoretical chemistry are subject of computational chemistry.

The elements

Now it is time to start looking at chemical elements. What happens if we have for example 10 g of magnesium and we start dividing that amount into smaller portions? Do we receive a new substance in such a process?

The answer is of course no. We may eventually arrive at the smallest portion of magnesium, which in chemistry is called an atom.

Democritus (ca. 460 BC) in Greece authored the atomic theory of the Universe.

John Dalton (1766-1844) created the modern atomic theory.

The main points of Dalton's atomic theory were:

* Elements are made of extremely small particles called atoms.
* Atoms of a given element are identical in size, mass, and other properties; atoms of different elements differ in size, mass, and other properties.
* Atoms cannot be subdivided, created, or destroyed.
* Atoms of different elements combine in simple whole-number ratios to form chemical compounds.
* In chemical reactions, atoms are combined, separated, or rearranged.

Elements in chemistry have their symbols, which consist of either a capital letter only or of two letters from which the first one is capitalized. The symbols of chemical elements have their origins in Latin or Greek names of the elements.

H hydrogen
O oxygen
N nitrogen
C carbon (Latin: Carbo *coal*)
Au gold (Latin: Aurum)
Cu copper (Latin: Cuprum)
Ag silver (Latin: Argentum)
F fluorine
Cl chlorine (Greek: Chloros *pale green*)
I iodine
Na sodium (Latin: Natrium)
K potassium (Latin: Kalium)
Ca calcium (Latin: Calcium)
Mg magnesium (Latin: Magnesium)

Fe iron (Latin: Ferrum)

Today's concepts of atom were developed at the beginning of the 20-th century after interpretations of experiment performed by Ernest Rutherford (1871-1937). It was famous thin gold foil experiment. In this experiment known to be positively charged alpha particles from a radioactive source were directed towards a thin gold foil and were deflected what suggested that the atoms of gold have a heavy positively charged nucleus and a cloud of negative charge around it consisting of electrons. A heavy atomic nucleus and electrons orbiting it give rise to the planetary model of the atom.

A name of a French chemist today was mentioned. Do you remember his name? Louis Pasteur

References

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