States of Matter

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There are three states of matter which exist in the environment of the Earth and there are two more states which exist in temperature extremes.

I. The Three States of Matter

The three states of matter most important to chemistry are solid, liquid and gas. Chemistry deals more-or-less in the temperatures that these phases exist in. The definitions of each:

solid: definite shape, definite volume.
liquid: indefinite shape, definite volume.
gas: indefinite shape, indefinite volume.

Indefinite shape means that the sample in question takes on the shape of the container. If some water was poured from a round container into a square container, the shape of the sample would change.

Indefinite volume means the sample would expand to fill the entire container. Only gases do this. If I had a sample of gas in a 5-liter container and moved the gas sample into a 10-liter container, the gas molecules would move farther apart from each other and fill the entire 10-liter volume. Note that, in doing this, the gas would become less dense.

Definite (for both shape and volume) means that the container makes no difference whatsoever. If 5-liters of liquid water is poured into a 10-liter container, the liquid would occupy 5-liters of the container and the other 5-liters would be empty. Suppose some water was frozen in the shape of a sphere and then put into a larger cubical shaped container. The spherical ball of ice would retain its spherical shape as well as retaining its volume even though it had been put into a container that was both larger and of a different shape.

II. Plasma and Bose-Einstein condensate: the other two states of matter

These two states of matter exist at temperature extremes. They ae interesting and useful to study, but are considered to be part of physics, not chemistry. This is because chemistry studys tend to be more-or-less close to room temperature and room pressure. These two states of matter might be considered, to use a favorite word of this era, extreme.

A plasma is created at several million degrees Celsius. In a plasma, all the electrons have been stripped from the atom and are free to move about. For example, each gold atom normally has 79 electrons. Forming a plasma with a sample of gold atoms means each atom has lost all 79 electrons. So a plasma has two things in it: free electrons and the bare nuclei of the atoms.

The high temperature is required for the existence of the plasma. As the temperature falls below the several million degrees required, the electrons begin to return to the atom and take up their usual places within the atom. Plasmas can be made on Earth using the proper (very expensive!!) equipment, but only in very small amounts for short periods of time. Plasmas were first successfully prepared sometime in the 1950's (I think) and have been a subject of study since then.

Bose-Einstein condensates are the reverse of plasmas. These exist only at very, very low temperatures, close to absolute zero. The existence of this state of matter was proposed by Albert Einstein in 1924, having been inspired by a 1924 paper by the relatively unknown Satyendra Bose. However, the technical demands of preparing a Bose-Einstein condensate was so great that it was not until 1995 that success was obtained.

Imagine 2000 people milling about in a field. From above, we look out and say "Oh yes, there are 2000 people. I can see each one and distinguish each one from another. I'll take a moment and count them." Of course, we can do this because people are different from each other.

Now imagine 2000 atoms of rubidium together in a small space and at a very, very low temperature. Keep in mind that atoms ARE NOT people. Each atom is a "separate" entity, but they are identical in many respects also. Same number of protons, some distribution of electrons, governed by the same laws of nature. In many important ways, one rubidium atom is completely indistinguishable from another.

This identical nature of the atoms results in a remarkable behavior of the 2000 rubdium atoms at something around 200 billionths of a degree above absolute zero. The 2000 atoms merge into one "superatom" of rubdium. This is the Bose-Einstein condensate. It is NOT 2000 little pieces stuck together. It is one entity and it is the element rubidium.

This first Bose-Einstein condensate lasted for 10 seconds, several people have won Nobel Prizes for work in this area and research continues today.

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