THE KINETIC MOLECULAR THEORY

The best qualitative explanation of the kinetic molecular theory that I have ever seen was presented by the late Professor Howard L. Ritter years ago in his textbook *An Introduction To Chemistry*, now out of print. Through the kindness of Mrs. Marie K. Ritter we were permitted to reprint Dr. Ritter's summary of the kinetic molecular theory and his descriptions of the kinetic molecular pictures of gases, liquids and solids presented below.

-- John H. Bedenbaugh

The Kinetic Molecular Theory

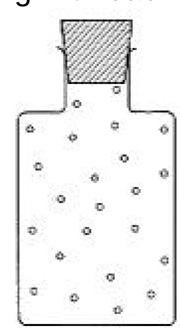
(1) Matter is composed of exceedingly small discrete particles called molecules. Each different kind of matter is made up of its own kind of molecules, every molecule of any one kind being exactly like all others of that kind and different from those of any other kind.

(2) These molecules are in rapid and ceaseless motion. Their average kinetic energy is greater the higher the temperature, and is dependent only on the temperature.

(3) The molecules are endowed with force fields that cause every molecule to exert an attraction on every other molecule.

The Kinetic-Molecular Picture Of A Gas

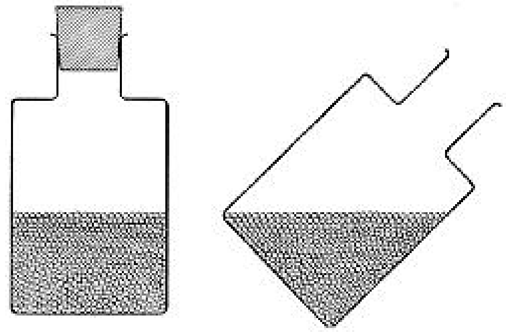
The molecules of a gas are separated by large vacant spaces many times the size of the molecules themselves. They are moving rapidly in all directions, colliding with each other and exchanging energy. At a given moment some molecules will have very high kinetic energy (fast-moving molecules) and others will have very low energy (slow ones). The average kinetic energy of the whole mass of gas, however, will be constant (conservation of energy) unless the total energy is changed by raising or lowering the temperature. The individual molecules of two samples of different kinds of gas at the same temperature have the same average kinetic energy. The rapidly and randomly moving molecules collide also with the walls of their container, the resultant continuous bombardment being the origin of the pressure exerted by a gas. Each molecule exerts and attractive influence on every other, but they move too rapidly for any permanent union to take place. This freedom of motion of the molecules in a gas accounts for its most distinctive gross characteristic -- the ability to expand in all directions to fill completely any container in which it is placed and to move freely out of an open container.



A gas consists of widely separated and independent, moving molecules.

The Kinetic-Molecular Picture Of A Liquid

The molecules of a liquid are packed closely together and lie at all times within mutual fields of attraction with their neighbors. The intermolecular distances average about the same as the size of the molecules themselves. Any chosen molecule may momentarily move rapidly enough to escape the combined field of its neighbors, but it immediately thereafter enters the field of its neighbors, but it immediately thereafter enters the field of others. Thus, though the near neighbors of any given molecule are continuously changing by this shuffling, the state of almost constant collision among the closely packed molecules prevents the freedom of molecular motion which obtains with a gas. The essential point is that in liquids the temperature is so low that the kinetic energy of the average molecule is not great enough to allow the molecule to leave completely the field of the others, while at the same time the molecules do have enough energy to break partially the attractive forces and continuously change neighbors. This restricted freedom accounts for the most distinctive characteristic of the liquid phase -- the ability to assume the shape of any container in which it is placed, yet to bound itself at the top by its own free surface.

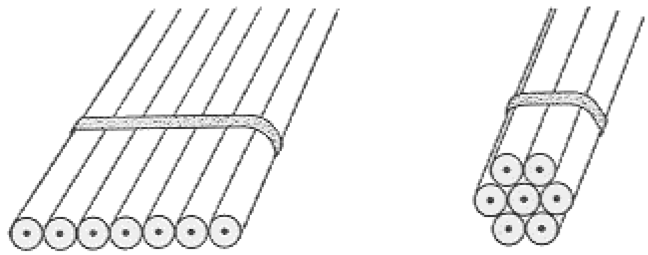


The kinetic-molecular picture of a liquid. The molecules are in chaotic disorder, closely crowded, and continuously reshuffling themselves. Mutual attraction holds the molecules closely together. They fall to the bottom of the container and are sufficiently free of each other to form a level surface and to pour easily.

The Kinetic-Molecular Picture Of A Solid

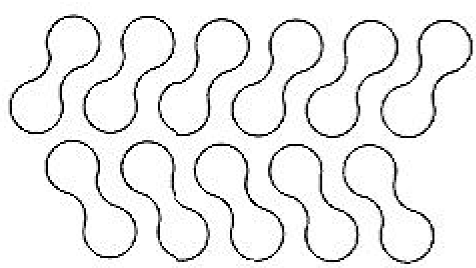
Representing a phase in which the energy is still lower than that of the corresponding liquid, solids have their freedom of molecular movement still further restricted. In a solid there is no longer a wandering of molecules; each molecule has a permanent selection of nearest neighbors, and its energy is too low to escape their combined fields of attraction. Here a new aspect of the attractive fields assumes importance: the directional or orientational aspect. Not only do molecules possess attractive fields, but these fields show certain directions of preferred attraction. Thus when the kinetic energy becomes so low that every molecule is permanently trapped amid fixed neighbors, the molecules tend to align themselves in a fixed pattern according to the particular preferred directions of attraction of the molecules concerned. The pattern depends on both the size and the shape of the molecules as well as on the directions of maximum attraction, and the particular pattern assumed is that of lowest potential energy.

That a mere reduction of potential energy may cause a group of objects to assume a geometrical pattern is easily demonstrated by a simple experiment: let the molecules be represented by a group of seven pencils arranged with their axes parallel. Since these molecules have no attractive fields on the scale that we require, let the fields be supplied by wrapping a small rubber band around them. If the pencils are now arranged with their axes parallel and all lying in one plane as shown on the left in the figure below, the rubber band will have to be stretched, and will therefore have a relatively high potential energy.   As soon as the whole system is left to its own devices, however, the rubber band will contract as far as it can and thereby reduce its potential energy. In doing so the pencils will arrange themselves, as on the right, in a centered hexagon, automatically and as the simple result of the system's attempt to reduce its energy.

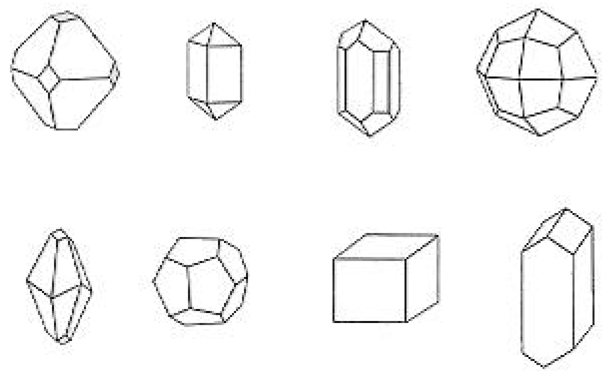


How a reduction in potential energy can form a geometric pattern. Seven pencils wrapped with a rubber band. On the left: rubber band stretched, high potential energy. On the right: rubber band relaxed, low potential energy, pencils in patterned arrangement.

Something formally similar to this happens in the patterned arrangement of molecules in a solid. The variety of such patterns is infinite, different for every material. This tendency is manifested externally in the propensity of solid substances to form crystals, the fixed geometrical form of crystal-line substances being the outward expression of the tendency of their molecules to arrange themselves in a geometrical array. It must be emphasized that the molecules in a solid are not motionless, but rather that their motion is restricted to vibration about a fixed position. The highly restricted motion of molecules in the solid phase accounts also for the most distinctive gross characteristic of solids: their rigidity. It may also be noted that crystallinity is characteristic of solids: practically all solids are crystalline, although this is not always apparent to the unaided eye.



One of the ways in which molecules can arrange themselves to form a crystal.



A few typical crystal forms. Every different material has its own highly characteristic crystal form in the solid state.