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Colloids

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COLLOIDS

The increasing importance of the chemistry of colloids is giving them a wide recognition in the general chemistry texts of college grade. In a lesser degrée they are included in the high school books but the information is often so condensed as to offer little of value. The writer believes that two or three class periods near the end of the year's eourse should be devoted to this subject and this article will attempt to present· basic fact upon which may be built a discussion of colloids for high school pupils.

Thomas Graham while studying diffusion in 1861 proposed that solutes should be divided into two classes: crystalloids and colloids. The former, as the name indicates, are in general capable of being crystallized and include such substances as acids, bases and salts. The latter, whose name means "glue like," are usually non-crystalline and are typified by glue, gelatine and egg white. To Graham's mind, substances naturally and unalterably belonged to one class or the other. Later study has revealed that substances can be changed at will from one condition to the other. So we now speak of the "colloid state."

Analysis of the results of adding a finely divided solid to a liquid will indicate three possibilities. The added material may disappear entirely, dissolve. Theoretically every molecule has been separated from its fellows, a case of complete molecular dispersion. A solution is characterized by its molecular dispersion, complete homogeneity and absence of settling. And it is so clear that a beam of light shot through it makes no visible path. It is said to be "optically empty."

Consider the possibility at the other extreme. The fine particles may, if insoluble, become scattered through the liquid and make it cloudy. Finally, if undisturbed, they will settle out. The finest of such particles are approximately at the lowest limits of microscopic visibility. Such a material is called a suspension. A solution and a fine suspension differ essentially in the size of the contained particles.

A wide range of particles are still to be considered, the range from the largest molecule of a solution up to the smallest microscopic particle of a suspension. Matter within this range of sizes is designated as "colloidal" and the division of physical chemistry dealing therewith is called "colloid chemistry." Mathematically expressed, the sizes vary from one ten thousandths to one millionth of a millimeter.

Although solutions, colloidal dispersions and suspensions differ fundamentally in the sizes of material involved, these states of subdivision impart peculiar properties. Hence we can experimentally differentiate, though not sharply, between the three classes.

The illustrations have dealt with one form of matter: grains. A noted colloid chemist, Dr. Wilder D. Bancroft of Cornell university, has aptly defined the whole field as "grains, drops, bubbles, filaments and films." Nor need water make up the main bulk. It is necessary only to have the colloidal substance mixed with some other phase. Theoretically, any of the three states of matter, solids or liquids or gases, may be dispersed in each of the three states, thus offering nine possibilities. Dr. Harry N. Holmes of Oberlin college, also a colloid authority, lists: grains dispersed in a solid, as gold in ruby glass; grains dispersed in a liquid, as colloidal gold in water; grains dispersed in a gas, as visible smoke;

drops dispersed in a solid, as water in butter; drops dispersed in a liquid, as oil-in-water emulsions; drops dispersed in a gas, as fog; and so through the list. The grains or other colloid are referred to as the "dispersed phase" or "discontinuous phase." The other material is termed the "dispersion medium" or "continuous phase."

That the dispersed phase may even possess the greater bulk is evident if we will imagine a lake dotted so full of tiny islands that only thin threads of water appear to separate them. The islands or dispersed phase evidently have more surface or bulk than the water or dispersion medium. It will appear, also, that the water is truly continuous and the land discontinuous.

Colloids may readily be prepared by a variety of methods. Let us consider a few general processes with illustrations. Grinding persistently by hand or with the modern colloid mill will reduce some solids, such as clay, to such fineness that when mixed with water they form a colloid. Adding water to hard glue or gelatine will bring it to the colloid state, a process called peptizing with a liquid. The method of double decomposition in low ion concentration can be illustrated by mixing solutions of arsenic oxide and hydrogen sulfide. The resulting colloidal arsenic sulfide imparts a hazy yellow color. Insoluble, colloidal ferric hydroxide is easily made by pouring ferric chloride solution into boiling water. The process is hydrolysis. If hydrogen sulfide solution is allowed to stand for some hours, colloidal sulfur appears by a process of oxidation. Another classic example is the addition of a little oil to water containing some soap, a process of emulsification.

If colloids are to remain permanently dispersed, certain precautions must be observed. A study of such precautions will here serve as a basis for presenting several important facts about colloid chemistry. The grain type, if pure, will exist indefinitely due to a remarkable phenomenon. To develop this point, let us start with a homely illustration. Mr. Jones takes his stand on a hill. Mr. Brown, armed with a mirror a foot square, goes off through the valley to another hill a half mile away. Brown, holding the back of the mirror toward Jones, telephones, "Can you see the mirror." "No, it is too small to see from here," answers Jones. Brown then turns the mirror about and directs the sun's reflection into Jones' eyes. "Now," says Jones, "I can see a little point of light where you are standing." The point of light, reflected from the invisible mirror could be seen over the half mile valley. If a beam of light from the sun or from a movie projector were allowed to enter a darkened room and the air of the room were perfectly pure, the light could be seen only where it struck the wall or screen. In the ordinary room, however, an ever widening path of light (a cone) could be traced clear across the room. The millions of very tiny dust particles in the air are too small to be seen, but they reflect myriads of points of light and produce the visible light path—the Tyndall cone. As before mentioned, a solution is optically empty because there are no tiny particles to reflect light; but a colloidal dispersion renders visible the path of a light beam. Now arrange a high power microscope so that a powerful beam of light from a special lamp can be sent across the stage, directly below the objective. Such an arrangement is called an ultramicroscope. If a grain type colloid is set upon the stage so that the light passes through it, an observer looking through the eye-piece will be thrilled to see many tiny points of light darting here and there. The light points are reflected from the otherwise invisible colloid particles. They dance about because the colloid particles are so light that the molecules of the liquid, usually water, in their constant motion bump the colloid particles here and there as a group of boys might kick a football about. This phenomenon, first observed by the British botanist, Brown, is called the Brownian movement. It easily explains why many colloids never settle.

The arsenic sulfide previously mentioned is a negative colloid, carries a negative charge on each particle. When such particles approach each other, their like charges repel,

hence they cannot come together and settle out. This explains the permanancy of many colloids. Now let us see what would happen if positive charges are introduced. If a salt, for instance, is added, it will dissociate into positive and negative ions. If the positive ions are very numerous they will collide with and neutralize the negatively charged colloid particles, resulting in the coagulation of the colloid. It is to be noted that the greater the valence of the oppositely charged ions, the greater their coagulating power. For instance, trivalent aluminum ions will have greater coagulating power on the negative arsenic sulfide colloid than will monovalent sodium ions. This will explain why, in the preparation of colloids by double decomposition, the ion concentration must be low.

How, then, can we stabilize a colloid which may be formed in the presence of strong electrolytes? Graham noted that if a mixture of his colloids and crystalloids were hung in water in a sack made of such materials as parchment, animal membranes, and the like, the crystalloids could pass through into the outer water but the colloids could not. In this way the electrolytes can be removed. Such a membrane he called a "semi-permeable" membrane and the process of separation is termed "dialysis."

The dialysis process suggests another colloid phenomenon which may be discussed here. Over the large end of a thistle tube stretch a colloidal membrane, let us say parchment paper, which is permeable to water but not to sugar. Place a sugar solution in the bell of the tube and immerse it in a beaker of pure water, supporting it in an upright position. There is a tendency for water to flow through the semi-permeable membrane in the direction which will bring the liquid on both sides of the membrane to the same concentration. Hence water flows into the tube, or cell, causing the water to rise higher and higher in the tube. The phenomenon is called "osmosis" and the hydrostatic pressure represented by the weight of the column of water is termed "osmotic pressure." The true osmotic pressure here is inherent in the sugar molecules. If the outer solution, instead of being pure water, were a more dilute sugar solution the result would have been similar. If the outer solution of sugar were the more concentrated or, speaking technically, had the higher osmotic pressure, the main flow of water would be out of the thistle tube, thus increasing the volume of the outer liquid. Stating generally, the main osmotic flow of liquid is always from the region of lower osmotic pressure to the region of higher osmotic pressure, The flow into the cell is called "endosmosis" and that outward, "exosmosis." Both always are existent, but one preponderates, with one exception. If the liquids on both sides of the membrane are of equal osmotic pressure, the volume of both liquids remains unchanged. Such liquids are said to be "isotonic."

Emulsions, such as the one mentioned above, are stabilized because each tiny particle of oil has an envelope of soap film about it. When particles carrying this colloidal protective film bump against each other, they do not coalesce, but rebound instead. Permanency of the colloid is here due to a protective film, which itself is a colloid of the film type. If an acid were added, it would destroy the soap film by changing it into a fatty acid and the oil and water would separate into layers.

Colloids may be classified as suspensoids and emulsoids. The grain type belongs to the former and the film type, to the latter. It may be factually stated that suspensoids do not appreciably increase the viscosity of the dispersion medium; that they are easily coagulated; and that they are irreversible, that is, if they are once coagulated or separated out they cannot readily be reconverted to a colloid. The reverse of these statements is true for emulsoids.

Emulsoids may exist in two conditions: the sol and the gel state. When the housewife first makes her winter's jelly or when she first prepares her jello dessert the result is a "sol," an emulsoid colloid in the liquid condition. After the jelly or jello have stood for some time they will, we hope, become very thick.
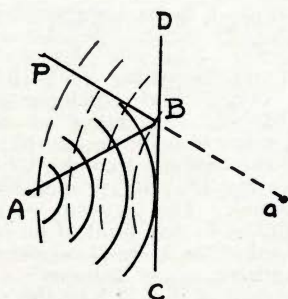
Fig. 3

located at the point A is producing sound waves. These waves proceed from A with wave fronts radiating in all directions. Suppose that the waves moving to the right strike a large plane surface CD and are reflected as indicated by the curved dotted lines which are drawn as if they came from the point A. Assuming the distance of the point P to be a hundred or more yards from the surface CD, an observer located at the point P would hear two sounds: one direct from A and the other, more faint, coming apparently from a point, a, as far behind the surface CD as A is in front of it. The point a, which is the center of the reflected wave, is called a sound image of the point A. The faint sound heard by the observer at P is popularly called an echo. An echo from a steep bluff or the side of a dense thicket of trees always seems to come from a point behind these objects: in fact, from a point just as far behind them as the hearer is located in front of them.

Repeated echos sent back and forth from the walls of an auditorium or from the sides of adjacent mountain peaks are called reverberations. An auditorium in which the reverberations are maintained for several seconds after the word is spoken is not desirable for public speaking. The reverberations of a room or auditorium for best hearing should not persist for more than a second or two.

Finally, not all waves produced by vibrators in elastic media are sound waves. Only those are sound waves that effect the auditory nerve. The normal ear hears sound waves when their frequency falls between 16 and 30,000 per second. Of course there are exceptional ears that might exceed these limits. Furthermore, sound waves are decidedly earthly phenomena. This means that they can only exist in the molecular media of our earthly surroundings. Sound waves can not be produced or propagated through a vacuum or through ethereal space. The good souls who hope to be able to sing praises to A Supreme Being when they pass into the ethereal realms will not be able to do so by means of our earthly sound waves. If the man in the moon ever sends a communication to his earthly neighbors it will not be by means of sound waves.

L. Begeman.

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COLLOIDS

They have entered the "gel" state. These states are often reversible. Warm them and they become fluid. Allow them to cool and stand and they again become thick.

The property associated with colloids called "adsorption" and applied so effectively in the canister of the gas mask and in cleansing with soap is highly interesting and important. It cannot be developed in the space assigned to this paper.

Applications of colloids are not so difficult to select or present as are the underlying principles and the organization of material. Hence the writer has chosen to use his space in the Bulletin for the more technical side of the topic. A dozen applications, taken at random, are: body processes, plant growth, glues, artificial silk, dyeing of fabrics, photography, rubber, cooking, ore, flotation processes, paints, inks and ceramics.

May we again urge every teacher of chemistry in our high schools to give a little time to this highly important subject—important in both its theoretical and applied aspects.

R. W. Getchell.