By means of this experiment students are readily converted to the practice of attempting to grind at one time only slightly more material than will cover the bottom of the mortar. The wide limits shown in the last column of the chart can hardly be attributed to anything but failure to observe this simple rule.

It should be added that the project method of approach and the element of competition combine to make this experiment very interesting to both students and instructors.

A BRIEF DISCUSSION OF THE IONIC THEORY IN ITS RELATIONSHIP TO CERTAIN LIFE PROCESSES.*

BY ROBERT C. WILSON.[1]

All life processes be they animal or vegetable are complex, and all materials for carrying on these processes are complex. Animal matter shows on analysis (chemical) that it is composed of many elementary substances which have associated themselves into various combinations, constituting many different kinds and types of molecules which vary in complexity from two to perhaps many hundreds of atoms. We cannot go very far into tracing the many chemical changes under which these elements may pass as they enter into and pass through complex life processes, without an application of certain principles which have come to us through a knowledge of "ionization."

A BRIEF RÉSUMÉ OF THE THEORY OF THE ION.

Pure water or a perfectly dry salt is a non-conductor of electricity. When HCl or a chloride or other salt or acid is dissolved in water, it is then found that the solution will conduct electricity. Something then has happened other than the mere physical phenomenon of "solution."

When a substance, on dissolving in water, gives to the solution the power to conduct electricity, that substance is called an "electrolyte." When an electrolyte dissolves in water, and we find that it has given this property of acting as a carrier for electricity, we have reason to believe that the electrolyte, on dissolving, is divided into its constituent atoms or groups of atoms, and that each atom or group of atoms bears a charge of electricity. Further, it is found that certain of these atoms or groups of atoms bear a positive charge of electricity while others bear a negative electrical charge, as evidenced by the fact that when a current of electricity is passed through such a solution, the atoms bearing a positive charge will collect at the negative pole, while those bearing a negative charge will collect at the positive pole. *Such an electrically charged atom or group of atoms is called the "ion"* and the "ion" may be composed of one or many atoms, *i. e.*, Cl, OH, SO_4, C_2H_5, etc.

The "ion" must not be confused with the atom, *i. e.*, NaCl or HCl on dissolving in water give no evidence of free Cl, but at the same time by disturbing the elec-

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trical charge of the "ion," it may be converted into the atomic state, and this very change is probably constantly taking place in body processes. In so far as the Cl "ion" is concerned, regardless with which chloride we may deal, its properties in so far as its "ionic" properties are concerned will be the same, *i. e.*, $FeCl_3$, NaCl, $ZnCl_2$, $HgCl_2$, etc. On the other hand on considering the metallic or positively charged ion, *i. e.*, Mg, Ca, Fe, Na or K, etc., the properties of these ions will always be the same regardless of what salt of the metallic ion is used, *i. e.*, $CaCl_2$, $CaBr_2$, $CaSO_4$, $Ca_3(PO_4)_2$. However, we must bear in mind at this point that ferrous and ferric, mercurous and mercuric, as well as other "ic" and "ous" salts or "ions" are entirely different in their physical, chemical and physiological properties except for the fact of their ready conversion one into the other through the addition or withdrawal of positive charges of electricity, and this phenomenon is constantly going on in body processes involving the ions of many elements.

The solubility of a salt in water determines the degree to which it can ionize, though it must be borne in mind that all readily soluble salts do not ionize to the same degree. We use the terms "weak" and "strong" to indicate the degree to which an electrolyte may ionize.

RELATIONSHIP OF IONIZATION TO OSMOTIC PRESSURE.

In any consideration of body processes, we cannot overlook the part osmotic pressure plays in all life processes. Osmotic pressure has been defined as "the force which determines the movement of water through or across the many membranes of living tissue." All electrolytes exert a certain influence to raise osmotic pressure and each electrolyte shows its own peculiar property in this direction. The influence of electrolytic dissociation has been proven to be the determining factor in this individual influence on osmotic pressure. All electrolytes do not dissociate into the same number of ions and it is this variation in dissociation which accounts for the variation in osmotic pressure with different electrolytes.

Having now some foundation as to the meaning of the terms "ion" and "dissociation," "electrolyte" and "osmotic pressure," we may attempt an application of these principles to physiologic processes:

Water, in a pure state, is dissociated into its component ions H and OH only to an infinitesimal degree, certainly not to an extent whereby it becomes a conductor of electricity; hence, pure water cannot have any appreciable osmotic pressure. When, as in this case, H and OH ions are present in the proportion to form water (HOH), and there is no excess of either ion, a condition exists which is known as "chemical equilibrium." There are, however, changes going on in body processes whereby this ratio between H and OH ions is being constantly disturbed, there being an excess of H ions producing an acid condition or an excess of OH ions producing an alkaline reaction or condition.

In normal saliva, a slight excess of OH ions is present, accounting for its mild alkalinity, this probably arising from the fact of the presence in saliva of an electrolyte or salt which on dissolving in the aqueous fluids of the mouth gives off free OH ions; and any condition which alters the normal alkalinity or concentration of OH ions has a direct effect upon the amylolytic enzyme in saliva destroying its digestive powers, and may result in the establishment of conditions conducive to disease. It is conceivable that the presence in great excess or the absence of some particular ion (Na, K, Ca or Mg) accounts for such a change in saliva, but however this may be, there is some disturbance in the proportion of H and OH ions.

Likewise, in the stomach, under normal conditions, we find an acid condition, this being due to the presence there of free H ions. *In the light of the ionic theory, we cannot say that the stomach contents contain free HCl,* nor can this be proven. True, we find there free H ions and Cl ions, but we also find Na and K ions, and lactic and butyric acid ions. Whether the original secretion was composed of Na or K or Ca lactate or butyrate and free HCl, or free lactic and butyric acids and NaCl or KCl no man can prove for we find there in the stomach contents all of these ions. But this we do know, that the proteolytic enzyme we call pepsin is active only in the presence of a certain acid concentration, or as we may now more properly say "a certain H ion concentration." Any change in this normal H ion concentration results as we well know in digestive disturbance. If such a digestive disturbance should come, may it not be accounted for by the presence of an excess of certain positive or negative ions or perhaps a diminution of these in the secretory vessels themselves? True, it must be that a proper ratio between H and OH ions must exist to give to these vessels the proper stimuli.

In the intestinal tract, there prevails under normal conditions a mild alkalinity which is accounted for by the presence of certain bile salts which in aqueous medium give off free OH ions. It appears that this mild alkalinity is necessary for the activation of the pancreatic enzymes, and any material increase or decrease in this concentration of OH ions results in digestive disturbances.

In such a brief and casual consideration of this very extensive and interesting subject, for the lack of time, we may not at this point pause to consider why H and OH ions influence the activity of these digestive enzymes, though such a procedure would be logical, but it would lead us into fields which are highly speculative as yet and but little understood. But we may stop to state our knowledge of the factors which increase or decrease H and OH ionic concentrations.

All acids and certain other electrolytes when dissolved in aqueous fluids give free H ions, and all bases and certain other electrolytes when dissolved in aqueous fluids give free OH ions. These base and acid forming radicals are present in our food and water, and are constantly undergoing chemical changes in the tissues and elsewhere in the body, affecting in turn the osmotic pressure in the tissues and the concentration of H or OH ions. The theory suggests itself that osmotic pressure is the determining factor in various body secretions especially in those cases where enzymatic influence is a factor.

In considering the ionic and osmotic properties of blood, the situation becomes even more complex perhaps than we have thus far encountered, because of the complex character of blood itself and the varying changes it undergoes in its circulation. There is present in blood at some time in its circulation, perhaps, some or all of the various ions which enter the body in food and water or which are formed in the tissues during digestion, secretion, absorption or excretion. A variation from the normal ionic concentrations results very promptly in variations in osmotic pressure, variations in assimilation, secretion, and excretion and in the concentration of H or OH ions with a resulting acid or alkaline reaction. Under normal conditions blood is perhaps slightly alkaline, though, during circulation, various acid products are being formed, among which may be mentioned carbonic acid. This is formed in the capillaries and during its passage through the venous system circulating in an aqueous medium we would expect to get free H ions and an acid reaction, but under normal conditions there are present certain electrolytes which suppress the ionization of this weak acid, and hence no H ions or acid reaction can exist. The elimination of CO_2 by the lungs removes this danger of an acid blood and to further offset the possible presence of H ions in blood, a supply of OH ions must be continually formed. To supply these alkaline OH ions, strike electrolytes, which in aqueous fluid yield them, must be constantly supplied since they are being constantly eliminated in the form of sweat, urine and feces.

A further factor of the presence of a proper concentration of electrolytes in the blood is the consideration of the osmotic pressure which is exerted within the blood cells—a lowering of electrolyte content resulting in a distension or possible rupture of the cell, while a heavy concentration of such electrolyte may result in compression of the cell. The positive or alkalinizing ions which are normally present in the blood are Na, K, Ca, Mg, NH_4, and Fe, while the negative or acid producing ions are Cl, SO_4, PO_4, uric, formic and other organic acid radicals.

A diet composed largely of vegetable foods which are rich in alkaline salts may result in hyper-alkalinity, while a diet of meats or other proteids which are rich in S, P, and N compounds may result in a hypo-alkalinity or conceivably an acidosis.

If time permitted, we might trace this matter of H and OH ion concentration and osmotic pressure in their relationship to urine, feces and milk secretions, but the principles already outlined will be left for your own application in these cases. For many years, we have been clinically aware of the presence of iron in the blood and of certain of its functions there, though perhaps we do not even yet consider its function properly in the light of possible explanations by the aid of the ionic theory. We have also observed clinically the presence of calcium and magnesium in the blood and other body products and perhaps noted the necessity of their presence in the clotting of blood, but other than this clinical observation we have not as yet attributed any other function to them.

We may also mention the fact of our knowledge that iodine is a necessary constituent for the proper functioning of the thyroid gland, but further than this observation we have not attempted to go. While as yet we have no knowledge concerning the activating principles in the adrenal and pituitary bodies, there is no doubt but that our knowledge of these now obscure products may be enriched within the near future by the application of the ionic theory to their study. Other than the three elements mentioned Fe, Ca, and I we are not now aware of any special function of the various other ions or electrolytes which are known to be essential for proper body processes and maintenance.

A study of the normal excretory products of the body reveals the presence of twelve or thirteen elements, and surely we may hope to be able to determine the particular physiologic function of each within the very near future.