In Two Parts.---No. 1.

A

TEXT-BOOK

ON

AGRICULTURAL CHEMISTRY,

FOR THE USE OF

ACADEMIES, SCHOOLS, AND AGRICULTURALISTS:

COMPRISING

THAT PORTION OF ELEMENTARY CHEMISTRY WHICH IS NECESSARY TO A FULL UNDERSTANDING OF THE CHANGES CONNECTED WITH VEGETABLE ORGANIZATION,

AND

AN EXAMINATION OF THE DIFFERENT MANURES, SOILS, CROPS, &c., COMPILED IN PART FROM THE WRITINGS OF PETZHOLDT, JOHNSTON, LIEBIG, AND OTHERS.

BY ASAHEL K. EATON, M. A.,

PROFESSOR OF THE NATURAL SCIENCES IN LITTLE FALLS ACADEMY.

UTICA:

H. H. HAWLEY & CO., AND G. TRACY.

1847.

Price Twenty-five Cents.

A TEXT-BOOK ON AGRICULTURAL CHEMISTRY,

FOR THE USE OF

ACADEMIES, SCHOOLS, AND AGRICULTURALISTS:

COMPRISING

THAT PORTION OF ELEMENTARY CHEMISTRY WHICH IS NECESSARY TO A FULL UNDERSTANDING OF THE CHANGES CONNECTED WITH VEGETABLE ORGANIZATION,

AND

AN EXAMINATION OF THE DIFFERENT MANURES, SOILS, CROPS, &c., COMPILED IN PART FROM THE WRITINGS OF PETZHOLDT, JOHNSTON, LIEBIG, AND OTHERS.

By ASAHEL K. EATON, M. A.,

PROFESSOR OF THE NATURAL SCIENCES IN LITTLE FALLS ACADEMY.

UTICA:

H. H. HAWLEY & CO., AND G. TRACY.

1847.

D. BENNETT, Printer,
156 Genesee St., Utica.

TO

DANIEL WASHBURN, ESQ., M. A.,

PRINCIPAL OF LITTLE FALLS ACADEMY,

This Volume

IS RESPECTFULLY DEDICATED

BY

THE AUTHOR,

AS A TRIBUTE OF ESTEEM FOR ONE WHO EVER MANIFESTS
A DEEP INTEREST IN THE ADVANCEMENT OF SCIENCE, AND ESPECIALLY IN THE SUCCESSFUL
APPLICATION OF ITS PRINCIPLES TO
THE USEFUL ARTS

PREFACE.

The demand for a text-book on Agricultural Chemistry, embracing that part only of chemical science which is intimately connected with the process of vegetable organization, has long been urgent. The publication of this volume is intended to supply that demand, and if it should prove the means of awakening a still greater interest in the beautiful changes connected with the phenomena of vegetable life, and of aiding the practical farmer in his endeavor to make fruitful the barren earth, the author will feel sufficiently rewarded.

There is a prejudice existing in the minds of some against "book farming" as it is called; the cause of this prejudice has been pointed out in almost the last words of a departed statesman, who was endeared to many, respected by all. "In many cases visionary experiments have been introduced, based upon no philosophical investigation of cause and effect, but upon some accidental trial by a single individual, of some novel mode of culture, which, under the circumstances attending the experiment has met with success. This single experiment, without an inquiry into, or knowledge of the cause, which, in the given cases has secured the successful results, is at once recommended as an infallible rule of husbandry. The publication and dissemination of detached experiments of this character, for a long period constituted the most material additions to the stock of literary information, connected with agriculture, supplied to our farmers; while many of the experiments were too intricate and complicated to be reduced to practice with any certainty of accuracy, and others were so expensive that the most perfect success would not warrant the outlay. Unsuccessful attempts to follow the directions given for making these, brought what came to be denominated "book farming" into great disrepute with the industrious, frugal and successful farmers of the country, and excited a jealousy of, and a prejudice against this description of information upon agricultural subjects, which it has caused years of patient and unceasing effort in any measure to allay, and which are not yet removed."

The deductions of chemical science are not *theories;* they are well defined and immutable *laws;* laws which never can be varied, for they were established at the dawn of time by the highest power, for the government of matter. The chemist sees changes occurring in the vegetable, animal, and mineral kingdoms, and it is his great inquiry, "What is the *cause* of this or that phenomenon?" In settling this question he has recourse frequently to *theories;* by experiments he tests the validity of these; if the true cause be once determined, he does not hesitate to assert that the same cause will ever produce a similar effect, in short he thus establishes the existence of a *law.*

It is true that there are very many points as yet unsettled in science, and many theories have been advanced to account for the phenomena connected with them; but it is easy to distinguish between the unfailing deductions of science and the uncertain assertions of theory. If a crop flourishes vigorously upon one soil, but upon another either fails entirely or is of a sickly growth; it is not impossible to ascertain the cause of the difference in agricultural capacity of the two soils; and knowing the elements that are wanting in that which is sterile, by proper treatment we may render it equal in productiveness to that which is naturally more fruitful. Some study is required in order to gain the requisite knowledge of the chemical constitution of plants, soils, and manures, but there is a manifest unwillingness, on the part of the practical farmer, to bend the mind to the acquisition of that elementary knowledge which is absolutely essential to the full understanding of whatever is written upon agricultural science.

Practical agriculturalists complain, and not without reason, that those works which treat of this department of science, although written by the ablest chemists, are of no use to those who ought to be most benefited by them, because their works are so interspersed with technical terms and *hard names* that it is impossible for those who are not chemists to understand them. The fault is to be attributed in part to the writers, in part, to the readers, of these treatises. On the one hand, such men as Liebig, Johnston, &c., have become so familiar with the use of chemical terms, that they do not consider that most men know very little of them, and hence they make use of such terms, even when common names might be substituted. On the other hand, many individuals have neglected to gain a knowledge of the elementary principles of chemistry, and therefore can not understand a general treatise upon the application of this science to agriculture, even if it is written in the simplest style possible, for, to many of the elements and compounds concerned in vegetation, no common names are given, and therefore chemical terms must be applied.

The superiority of chemical names over these in common use, is not justly appreciated; the latter usually mean nothing; the former generally indicate the exact constitution of the substances designated or their peculiar properties. In the following pages, the common name is used whenever any such exists, and the chemical term is given in connection with it. Rules also are given which enable the learner by a very little study, to determine the *constitution* of a compound from its *name*, or its name from its constitution.

It has been the endeavor of the author to introduce only that portion of elementary chemistry which is essential to a full understanding of the changes occurring in the vegetable world; in the last part of the work the principles of the science are applied, and the nature and action of different manures, the capabilities of different soils, and the kind of food demanded by different plants, successively examined.

Acknowledgements are due to the various authors quoted in the course of the work; no apology to the reader is required for compiling from the writings of such chemists as Johnston, Petzholdt, Draper and Liebig.

Little Falls, Dec. 1847.

AGRICULTURAL CHEMISTRY.

PART I.

ELEMENTS.

SECTION I.

CONSTITUTION OF MATTER.

NOTWITHSTANDING the variety of *forms* which the matter constituting the world assumes, there are, in reality, only about fifty-eight different simple substances, and the combination of these has produced most of the objects which we see around us. These simple substances are called *elements.* Gold, silver, copper, mercury, iron, sulphur, &c., are elementary substances, whilst air, water, earth and most kinds of matter with which we are familiar, are compound, formed by the combination of different elements.

There is a mineral—iron pyrites—that very nearly resembles gold, but, by subjecting it to certain tests, it is resolved into two substances, iron and sulphur. It is not then an *element*, because, by decomposition we obtain from it two different elementary substances: but *gold*, though very similar to this mineral in appearance, is an *element*, because it has never been decomposed.

How many different simple substances are there? How are most of the objects which we see around us, produced? What name is given to these simple substances? Mention some elements—some substances that are not elements. What is said of a certain mineral resembling gold? Is it an element?

B

Those bodies, whether solids, liquids or gases, which have never been decomposed, or divided so as to produce two or more different substances are called *elements;* some of these, by farther investigation *may* prove to be compound.

The science of Chemistry owes its origin to the fact that the number of simple substances is limited. Did the earth consist of but one elementary substance—iron for example—such a science would be uncalled for. If it were composed of as many as it seems to be to the uneducated, it would be almost impossible to establish such a science.

It is the legitimate object of Chemistry to point out the elements of which matter is composed, the laws which govern the union or separation of those elements, and the properties of the compounds formed by their combination.

By applying this science to the vegetable forms which flourish upon the earth, and to the manner in which they are nourished, we ascertain the elements of which plants are composed; the constituents of the soil, and the substances which it is necessary to supply to the soil, as food for the plant.

It is the province of Agricultural Chemistry then, to treat of those elements of which plants are composed, and the manner in which they are obtained, retained and united, to form vegetable substances.

In treating of the simple substances in this work, we shall dwell upon those only which are concerned in the formation of plants, since we do not wish to burden the mind with that which does not pertain to Agricultural

---

What substances are called elements? May some now called elements, prove to be compound? If the earth consisted of but one element, would there be any necessity for such a science as Chemistry? What would be the result if there were as many different simple substances as there are different forms of matter? What is the object of chemistry? What is the province of agricultural chemistry?

Chemistry. A list is given, however, of all the elements known, with the *abbreviation* or symbol, which is generally written instead of the whole name.

Elements with their Symbols and Atomic Weights.

Non-metallic Elements.	Symbols.	At. wts.	Metallic Elements.	Symbols.	At. wts.
Oxygen . . .	O.	8·013	Erbium . . .	E.	——
Hydrogen . . .	H.	1·000	Terbium . . .	Tr.	——
Nitrogen . . .	N.	14·19	Manganese . .	Mn.	22·72
Carbon . . .	C.	6·04	Iron	Fe.	28·00
Boron	B.	10·91	Cobalt	Co.	29·57
Silicon	Si.	22·22	Nickle	Ni.	29·62
Sulphur . . .	S.	16·12	Zinc	Zn.	32·31
Selenium . . .	Se.	39·63	Cadmium . . .	Cd.	55·83
Phosphorus . .	P.	15·72	Lead	Pb.	103·73
Chlorine . . .	Cl.	35·47	Tin	Sn.	58·92
Iodine	I.	126·57	Bismuth . . .	Bi.	71·07
Bromine . . .	Br.	78·39	Copper	Cu.	31·71
Fluorine . . .	F.	18·74	Uranium . . .	U.	217·20
			Mercury . . .	Hg.	202·87
Metallic Elements.			Silver	Ag.	108·31
Potassium . .	K.	39·26	Palladium . .	Pd.	53·36
Sodium . . .	Na.	23·21	Rhodium . . .	R.	52·20
Lithium . . .	L.	6·44	Iridium . . .	Ir.	98·84
Barium . . .	Ba.	68·66	Platinum . . .	Pt.	98·84
Strontium . . .	Sr.	43·85	Gold	Au.	199·2
Calcium . . .	Ca.	20·52	Osmium . . .	Os.	99·72
Magnesium . .	Mg.	12·89	Titanium . . .	Ti.	24·33
Aluminum . .	Al.	13·72	Tantalum . . .	Ta.	184·90
Glucinum . . .	G.	26·54	Tellurium . . .	Te.	64·25
Yttrium . . .	Y.	32·25	Tungsten . .	W.	99·70
Zirconium . .	Z.	33·67	Molybdenum . .	Mo.	47·96
Thorium . . .	Th.	59·83	Vanadium . .	V.	68·66
Cerium . . .	Ce.	46·05	Chromium . .	Cr.	28·19
Lanthanum . .	La.	——	Antimony . .	Sb.	64·62
Didymium . .	D.	——	Arsenic . . .	As.	37·67

It will be seen that these elements are divided into metallic and non-metallic, 13 of the latter, 45 of the former. The column of atomic weights gives the supposed comparative weight of an atom of each elementary substance. It is supposed that there is a limit to

For what are symbols used? How are the elements divided? What is indicated by the numbers in the column marked "atomic weights?"

the divisibility of matter, and those exceedingly minute particles of which a substance is supposed to be made up, are called atoms. The comparative weight of an atom of zinc and one of sulphur, are as the numbers 32·31, and 16·12, or, as they are generally given, 32 and 16. This is inferred from the circumstance, that if we decompose the simplest combination of these elements, which is an ore called *zinc blende;* we shall obtain 32 parts by weight of zinc, and 16 of sulphur from 48 parts of the ore.

The following list contains the names of those elements only, which are concerned in the production of vegetable forms. The atomic weights are given approximately.

Elements which constitute Plants.

Non-Metallic Elements.	Symbols.	At. Wts.	Metallic Elements.	Symbols.	At. Wts.
Oxygen . . .	O.	8	Potassium . . .	K.	40
Hydrogen . . .	H.	1	Sodium . . .	Na.	24
Nitrogen . . .	N.	14	Calcium . . .	Ca.	20
Carbon . . .	C.	6	Magnesium . .	Mg.	12
Silicon	Si.	22	Iron	Fe.	28
Sulphur . . .	S.	16	Manganese . .	Mn.	28
Phosphorus . .	P.	16	Aluminum . .	Al.	14
Chlorine . . .	Cl.	36			
Iodine . . . ,	I.	126			
Bromine . . .	Br.	78			
Fluorine . . .	F.	18			

These 18 elements are the only ones concerned in the process of vegetation, and of these, the first, second and fourth, form by far the larger proportion of the plant,—from 88 to 99 per cent. But notwithstanding the minute quantity of the other elements, a certain proportion, though very small is absolutely required: except a few of the elements which occur in certain plants only.

What are atoms? Why are 16 and 32 given as the atomic weights of sulphur and zinc? How many elements are concerned in vegetation? Which of these constitute the greater share of the plant? What proportion? Are the other elements essential to the perfection of the plant?

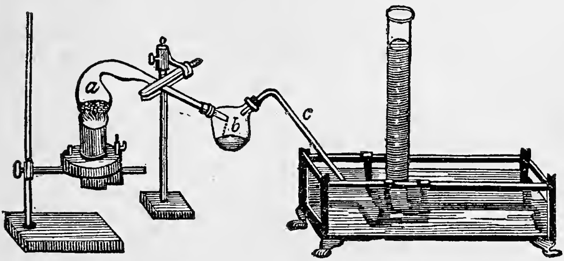
It is of the first importance that the student should pursue this study systematically, and in order to do this, he should first obtain a knowledge of these elementary substances, then of the compounds formed by the union of the same, and lastly, of those agencies by which the various changes are wrought, which are continually going on in the vegetable world. In this way he will obtain a knowledge of that part of elementary chemistry which is directly applicable to agriculture.

SECTION II.

OXYGEN, HYDROGEN, NITROGEN, & CARBON.

Oxygen. $O=8$.

Fig. 1.



If we introduce a portion of *red precipitate* into a *retort*, (*a*, Fig. 1,) and apply heat by means of a spirit lamp, a bright metal will soon begin to accumulate in the receiver (*b*); it is a liquid at ordinary temperatures, and is called *Mercury*. Whilst this metal is dis-

---

What is the symbol for Oxygen? What its atomic weight? What substance is placed in the retort, in the process represented by Fig, 1? What metal distills over and accumulates in the receiver?

tilling over from the retort, bubbles will appear at the end of the tube (*c*) which passes into the water of the cistern. The tall glass jar is filled with water, and inverted with its mouth over the end of the conducting tube; as the bubbles of gas pass from the tube, they rise in the jar and displace the water.

This gas is called Oxygen, and is the first in the list of elements.

It will be seen at once that it is very similar to air in its physical properties, being transparent, colorless, tasteless and inodorous. It is heavier than atmospheric air in about the ratio of 11 to 10. In its chemical properties it differs widely from air, as will be indicated by the following experiments.

Fill a small jar or a tumbler with this gas, and having covered its mouth with pasteboard, place it with the mouth upward. Remove the pasteboard and introduce an extinguished candle, (fire still remaining in the wick,) it will be instantly relighted, with a slight report, (Fig. 2.) If the gas is pure, this can be done several times in succession.

Fig. 2.

Oxygen then is a *supporter* of *combustion*. This property can be illustrated more brilliantly by another experiment. A piece of lighted phosphorous placed in a jar of oxygen, burns with a light so brilliant, that it is insupportable to the eye. A piece of charcoal ignited and placed in a vessel of this gas, burns rapidly, throwing off bright scintillations.

Its power to support combustion is not confined to those substances which we call combustibles, but many substances which are generally considered incombustible, are burned rapidly and with brilliant effect in oxygen.

What is collected in the inverted jar? What is said of the *physical properties* of this gas? In what ratio is it heavier than air? How is it shown that oxygen is a *supporter of combustion?* What different substances will burn brilliantly in oxygen?

Zinc, iron and steel wire, the diamond and other things called incombustible, are consumed if the temperature is sufficiently raised before they are placed in the gas.

To prepare the iron wire for burning in oxygen, it should be coiled about a small cylinder to give it a proper shape, and the end dipped in melted sulphur. The sulphur is ignited, and the coil placed in the bottle of gas, as in (Fig. 3.) A fine watch spring arranged in this way burns brilliantly, throwing off a shower of sparks.

Fig. 3.

Such is the heat of the globules of melted matter that drop off during the combustion of the iron wire, that after passing through a considerable portion of water in the bottle, they melt the glass, and are embedded in it.

The bottle in which the experiment is tried, should contain 2 or 3 inches depth of water to prevent its destruction by these globules. The cork to which the spiral wire is attached should fit loosely in the bottle.

Oxygen is not only a supporter of combustion in the experiments here given, but is *the great supporter of combustion* wherever it goes on. Supplied from the atmosphere, it feeds the fires of the furnace and the forge, the flame of the lamp and the gas light. Even the animal frame is warmed by a kind of combustion within, carried on by means of oxygen.

If a bird be placed in a confined portion of oxygen gas, it will live five or six times as long, as in the same volume of atmospheric air. It is, therefore, a supporter of animal life. If blood be agitated in oxygen, it changes to a bright vermillion color, and the same change is effected by the oxygen of which the air is in

---

Describe the experiment with a steel watch spring. Does ordinary combustion depend upon the presence of oxygen? Whence is it supplied? How is it shown that oxygen is a supporter of animal life? What is the effect of oxygen upon *blood*, agitated in a vessel of this gas?

part composed, in the blood of living animals. This is supposed to be the cause of *animal heat;* the nature of the change will be mentioned hereafter more particularly.

Oxygen appears to exist nowhere in nature in a disengaged state, but in a combined state it is more generally diffused than any other element.

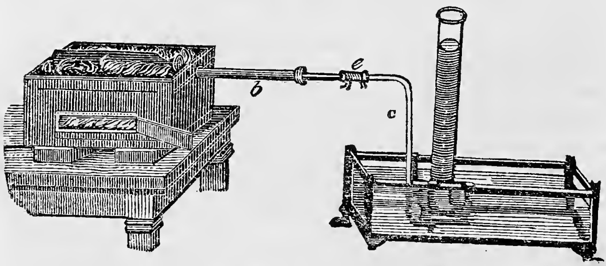
It constitutes eight ninths of the water upon the surface of the earth, one fifth of the surrounding air, more than one third of the mineral crust of the globe, more than one half of all animal substances, and *nearly one half of the vegetable forms growing upon the face of the earth.*

This gas is absorbed by water; 100 measures of the latter taking up 6 $\frac{1}{2}$ of oxygen.

Oxygen acts an important part in the production of vegetable forms, but this is not the proper place to enter into an examination of its influence upon plants. This part of the subject is deferred until the pupil is supposed to understand the nature of some of the more important compounds of Oxygen with other elements.

The process given for obtaining this gas, is not the one usually adopted, but it is given here on account of the simplicity of the changes connected with it.

Fig. 4.



What is the effect of this change when it is produced in the animal system? What proportion of water and air, also mineral, animal and vegetable substances, does oxygen constitute?

A more economical method for obtaining oxygen is represented by (Fig. 4.) A substance, known as *black oxide of manganese*, is introduced into an iron bottle, to which an iron tube (*b*) is fitted. The conducting tube (*c*) is connected by means of a tube of india-rubber, (*e.*) The bottle arranged in a furnace as represented in the figure, is made red hot, and oxygen is disengaged in the bottle, and collected in the jar. A common gun-barrel may be used instead of a bottle, where small quantities only are required.

Fig. 5.

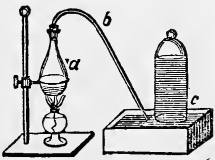


Fig. 5 represents another process for obtaining oxygen. The flask (*a*) contains a mixture of black oxide of manganese and *oil of vitriol*, two parts of the former to one of the latter. By the application of heat, oxygen is generated, and is collected as in the preceding processes.

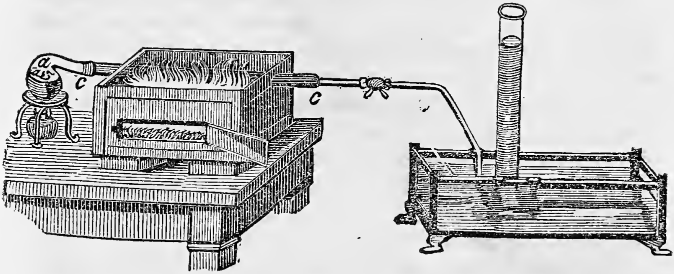
If a substance called *chlorate of potash* be mixed with the manganese, instead of oil of vitriol, the gas will be obtained much more easily and rapidly; if this mixture be used, an iron bottle or gun-barrel may be substituted for the flash, and arranged as in Figure 4.

Hydrogen. *H*=1.

In (Fig. 6,) we have a retort (*a*) containing water, connected with an iron tube, (*cc.*) This tube is filled with iron wire, and kept at a red heat by a furnace. If we apply the heat of a spirit lamp to the retort until the water boils, bubbles of gas will begin to appear, rising from the end of the connecting tube and filling the jar. This gas is called Hydrogen, and like Oxygen, is an element. It is colorless, transparent, and when pure, inodorous.

Give other processes for obtaining oxygen What is the symbol for hydrogen? Its atomic weight? Describe the process for obtaining it? What are its properties?

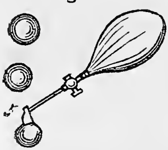
Fig. 6.



It is absorbed by water in very small quantity, 100 measures of water absorbing only $1\frac{1}{2}$ of hydrogen.

The most striking physical property of this gas is its extreme lightness, being 200,000 times lighter than Mercury, and 14 times lighter than common air. This property renders the gas applicable to aerostatic purposes, and balloons are generally inflated with it.

Fig. 7.



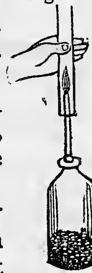
The principle of balloons is aptly illustrated by blowing soap bubbles by means of a bladder filled with hydrogen, and a tobacco pipe, as represented in (Fig. 7.) The bubbles will rise rapidly through the air, and if a lighted candle be applied, the gas will burn with a yellowish flame. Here we discover a new property of hydrogen—its inflammability.

If a jar of this gas be held with the mouth downwards, (on account of the levity of the gas,) and a lighted candle be immersed in it, the gas will be fired at the surface, and the candle will be extinguished in its passage into the jar, and relighted again at the surface as it is withdrawn. By this experiment, we are made acquainted with another property of hydrogen—it is a

What is said of its lightness? For what purposes is it used on account of its lightness? How is this illustrated? If a lighted candle be applied to the rising bubbles, what will be the result? What is the effect when a lighted taper is introduced into an inverted jar of hydrogen?

non-supporter of combustion. It will not burn unless oxygen be present. If we make a mixture of hydrogen and air—2 volumes of the former and 5 of the latter—and, confining it in a strong tube, fire it by applying a lighted taper to a small aperture, a violent explosion will take place.

Fig. 8.

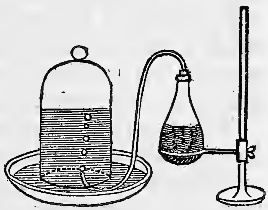


When a jet of hydrogen is burned at the extremity of a small tube, musical sounds can be produced by covering the flame with a large tube of glass or metal, as in (Fig. 8.)

These tones are occasioned by the rapid succession of slight explosions within the tube, which produce a vibratory movement of the air.

In this experiment the gas is obtained by placing in the bottle fragments of zinc, or iron filings, and pouring on a mixture of one part of oil of vitriol, and three of water. The jet should not be ignited until the air is expelled from the bottle lest an explosion ensue. The musical tones may be varied by moving the tube up or down, or by taking tubes of different sizes. Hydrogen is usually obtained by the action of dilute oil of vitriol upon zinc or iron, as in the experiment with the jet, and the apparatus may be arranged as in (Fig. 9.)

Fig. 9.

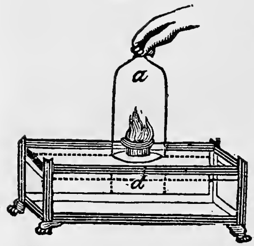


It is a non-supporter of respiration, although it does not prove instantly fatal when inhaled. This gas is not as extensively diffused as oxygen, constituting but a small proportion of the mineral crust of the globe, one ninth of water, and from 5 to 7 per cent. of vegetable substances.

What is the consequence of firing a mixture of hydrogen and air confined in a tube? How may musical tones be produced? How are they occasioned? How is hydrogen usually obtained? Will it support respiration? To what extent is it a constituent of plants?

Nitrogen. $N=14$.

Fig. 10.



Place a float upon the surface of the water in the cistern; lay a piece of phosphorus upon it, and having ignited, place an empty jar over it as in (Fig. 10.) As the phosphorus burns, white fumes will fill the jar, and the water will rise and occupy one fifth of the space, at first occupied by air. The white fumes will disappear in a short time, and leave a colorless gas called Nitrogen. It is devoid of taste or smell, and sparingly soluble in water—about the same as hydrogen in this respect.

Nitrogen is lighter than air in the ratio of 97½ to 100. A lighted candle immersed in this gas is immediately extinguished. Animals die in it, not from any poisonous quality of the gas, but on account of the absence of oxygen. From its incapability of supporting life, it is called *azote*. A moistened mixture of iron filings and sulphur may be substituted for the phosphorus in the process given, but a considerable length of time is required in this case, for effecting the required result.

This gas is an essential constituent of the atmosphere, forming about 80 per cent. of its bulk—does not occur in the mineral masses of the earth in any notable quantity, but forms a part of many animal and vegetable substances, and probably exerts a very important influence in the organization of plants.

How is nitrogen obtained? Describe its appearance and properties. How much lighter than air? Its effect upon flame and animal life? What may be substituted for phosphorus in the process for obtaining nitrogen? What proportion of the atmosphere does this gas constitute? What influence does it exert in the vegetable world?

Carbon. $C = 6$.

When wood is burned without free access of air, a substance called charcoal is produced. This charcoal consists of *carbon,* with a slight admixture of earthy matter. This form of carbon is light and porous, but other forms occur, such as plumbago, (black lead,) and the diamond, which are much denser. Newly prepared charcoal possesses the peculiar property of absorbing in large quantity, the moisture and various gases contained in the atmosphere. Its importance as a fertilizer seems to depend in a great measure, upon this property.

Carbon is an essential ingredient in all animal and vegetable substances, forming from 40 to 50 per cent. of the latter, and is found every where in air, sea, and earth, in combination with other elements.

Charcoal when applied to soils greatly promotes vegetation; not principally however, by supplying nourishment from its own substance, for it can not immediately enter the roots of plants, but as a medium through which many necessary gaseous constituents are conveyed to the plant.

SECTION III.

SILICON, SULPHUR, PHOSPHORUS, CHLORINE, IODINE, BROMINE, FLUORINE.

Silicon. $Si = 22$.

Silicon is a dull brown powder, obtained from *silica* by an intricate and difficult process. *Silica* is a com-

What is charcoal? What other forms of carbon are mentioned? What important property does newly prepared charcoal possess? To what extent is carbon a constituent of plants? How does charcoal promote the growth of plants? Describe silicon?

pound of oxygen and silicon, and is familiar to all under the forms of sand, quartz, flint, &c. Silicon when heated in the open air, takes fire on account of the union of oxygen with it, and forms silica again.

This element constitutes about one sixth of the mineral crust of the earth, and is always found combined with oxygen.

The compound *silica* is devoid of color, taste or smell, and is infusible except by the strongest heat. It is one of the most abundant substances constituting a portion of almost all soils, and occurs in the ashes of *all plants.*

Sulphur. $S=16$.

This elementary substance is too well known to require a description. The sulphur of commerce is obtained from the craters of volcanoes. It is brought up or sublimed by heat, and condenses in the fissures of the crater. Sulphur is heavier than water in the ratio of 199 to 100. It is found very extensively combined with the different metals, and is a constituent of animal and vegetable substances. It is insoluble in water, and is met with under three different forms: flowers of sulphur, lac sulphuris, and roll brimstone.

Although a constituent of plants, sulphur does not exert any very important influence, in its *uncombined* state, upon vegetation.

Phosphorus. $P=16$.

Phosphorus is a solid, usually of a pale yellow color, but when pure, transparent and colorless. At ordinary temperatures it is of the consistence of wax, but at a

---

What is silica? What different forms of silica are mentioned? How is silicon converted into silica? Whence is the sulphur of commerce obtained? How much heavier than water is it? Does it exert an important influence in its *uncombined* state?

low temperature is brittle. It is not found in an uncombined state, but is obtained from bones by the following process.

The bones are burned and then reduced to powder. This powder is acted upon by oil of vitriol diluted with water, the resulting mixture is strained, and the liquid part mixed with powdered charcoal. This mixture when dry is introduced into an earthen retort, and subjected to a high heat. The retort should have a tube of copper attached, which should pass beneath the surfaee of water. The phosphorus distilling over, condenses in the copper tube and flows down into the water.

Phosphorus is highly inflammable, and burns slowly at ordinary temperatures when exposed to the air. It takes fire and burns rapidly when heated slightly, and is readily inflamed by friction. It should be preserved in well stopped bottles, under water. If kept in the dark it will remain colorless, but exposed to the light, becomes red.

Phosphorus is found in nature, chiefly in the animal kingdom as a constituent of bones, but is contained also, in small quantity, in vegetable forms, and is a constituent of some minerals. Phosphorus is heavier that water in the ratio of 177 to 100.

Chlorine. *Cl*=36.

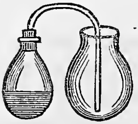
If into a glass flask, we introduce a mixture of common salt three parts, and a substance called the black oxide of manganese one part, and pour upon it two parts of oil of vitriol; by the application of heat, a greenish yellow gas will be produced. This is called *chlorine*. It has an exceedingly pungent, disagreeable odor, and

---

Describe phosphorus. Give the process for obtaining it? What is said of its inflammability? Where is it chiefly found? How much heavier than water? By what process is chlorine obtained? What is its color? Its properties?

extinguishes a lighted taper ; there are certain substances, however, which take fire spontaneously in this gas, phosphorus, gold leaf, arsenic, &c.

Fig. 11.



As chlorine is more than 4 times as heavy as atmospheric air, it can be collected in an open vessel with the mouth upwards, as represented in (Fig. 11.) It can not be collected over water, because this fluid absorbs twice its own bulk of the gas.

Chlorine exists in large quantity, combined with another element, forming vast deposits of rock salt ; it is also a constituent to some extent, of animal and vegetable forms.

A solution of chlorine in water, is said to hasten the germination of seeds.

Chlorine is remarkable for its great bleaching properties, and is used, in a state of combination with lime, for discharging colors.

Iodine. *I*=126.

Iodine is a bluish black solid, with a lustre somewhat metallic. It is obtained from the ashes of sea weed, sponge, &c.; but as it does not occur in any of the plants cultivated for food, we shall not dwell upon it here. It is concerned only in the production of *marine* plants.

Bromine. *Br*=78.

Bromine is a liquid of a blood-red color, and pungent disagreeable odor. It may be obtained from sea water, sea weeds, and brine springs. Like chlorine, it

---

What substances take fire in it spontaneously? How can it be collected? What is the effect of a solution of chlorine in water upon seeds? For what is chlorine remarkable? What is the atomic weight of iodine? Describe this element. In what plants does it occur? What is the symbol of bromine? Describe this element.

possesses bleaching properties, and will support the spontaneous combustion of certain metals. Like Iodine, it is concerned in the formation of *marine* plants only.

Fluorine. *F*=18.

The element to which the name fluorine has been applied, is somewhat imaginary, that is, it has never been isolated, although its existence has been rendered exceedingly probable. It occurs in several minerals, and in the teeth of animals. It has been recently ascertained that it is a constituent of the ashes of plants.

We shall consider it farther hereafter in its combined state.

SECTION IV.

POTASSIUM, SODIUM, CALCIUM, MAGNESIUM, IRON, MANGANESE.

Potassium. *K*=40.

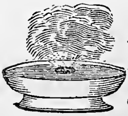
This element is a metal, and can be obtained by the following process. A mixture of potash and coarsely powdered charcoal is introduced into an iron bottle, and the bottle connected by means of a tube, with a vessel of naptha. Subjecting this to a white heat, the metal distils over, and condensing in the receiver in the form of globules, is protected by the naptha.

At common temperatures, potassium is soft like wax, its color bluish white. It is lighter than water in the ratio of 86½ to 100, and has such an avidity for oxy-

In what respect is it similar to chlorine? What is the atomic weight of fluorine? Where does it occur? What has been recently ascertained? Give the symbol and atomic weight of potassium. How is it obtained? Describe it.

gen that it will unite with it if exposed to the air ; it is necessary, therefore, to preserve it in a fluid that contains no oxygen—naptha is the substance used for this purpose.

Fig. 12.



If a piece of potassium be thrown upon water or upon ice, it will take fire, and burn with a pink flame, (Fig. 12.) This element is found in combination with other substances in the ashes of plants.

Sodium. *Na*=24.

If we repeat the process just given for obtaining potassium, substituting soda in the place of potash, a silver white metal will be obtained which is called *Sodium.* It is soft at ordinary temperatures, and lighter than water in the ratio of 93½ to 100.

If thrown upon water, and prevented from moving about, it will burn with a beautiful yellow flame. It must be preserved in naptha to prevent its uniting with oxygen. Sodium does not occur in its elementary state in nature, but in combination with chlorine, forms extensive deposits of rock salt; it is found also in the ashes of plants, and in union with other elements, as a constituent of many soils.

Calcium. *Ca*=20.

Calcium is obtained with great difficulty, and therefore has never been formed in sufficient quantity to allow a proper examination of it. It is a silver white metal, and is obtained from lime, which is a compound of oxygen and this metal. Thus combined, it consti-

---

Why is it necessary to preserve it in naptha ? How is sodium obtained ? Describe it. Describe the effects of potassium and sodium when thrown upon water. What does sodium form by its combination with chlorine ? Sodium is a constituent of what ? Describe calcium.

.utes a large portion of the mineral crust of the earth; it is also a constituent of the bony frame-work of animals, and is found in the ashes of plants.

Magnesium. *Mg*=12.

From magnesia, a white metal called magnesium is with difficulty obtained. If it be heated to redness it takes fire, uniting with oxygen and forming magnesia again.

It does not occur in nature in its elementary form, but combined with oxygen, is a constituent of many minerals and is found in the ashes of plants.

Iron. *Fe*=28.

It is hardly necessary to describe this element, since its appearance and properties are, in some degree, familiar to all. Its various applications in the arts render it more indispensable than any other element. Iron is found native, or uncombined in considerable quantities, yet most of the iron of commerce is obtained from compounds of oxygen with this metal. It is a constituent of plants and soils.

Manganese. *Mn*=28.

If we take the black oxide of manganese, and mixing it with lamp black and oil, subject it to the highest heat of a smith's forge, we shall obtain a grayish white metal, which is *manganese.*

It is eight times as heavy as water, very brittle and

From what is it obtained? Calcium combined with oxygen constitutes what? Give the symbol and atomic weight of magnesium. Whence is it obtained? Does it occur in its metallic form? Give the atomic weight of iron. From what is most of the iron of commerce obtained? What symbol is written instead of *manganese?* What is the atomic weight of manganese? How is it obtained?

exceedingly infusible. It does not occur native, but is widely diffused in combination with oxygen, being a constituent of most soils, although in small quantity. Traces of it are found in animal and vegetable substances.

Aluminum. *Al*=14.

This metal is obtained with great difficulty, never occurring in nature in the metallic form. In combination with oxygen, is the principal ingredient of all clays. In this form, it is also a constituent of many rocks and most soils, and exists in small quantity in the ashes of plants.

We have now examined successively, the 18 elements which enter into the constitution of plants. In doing so we have purposely avoided saying much concerning the part each element acts in the production of the plant, because this part of the subject requires a knowledge of certain compounds hereafter to be explained. Few of the elements enter into the circulation of the plant, in their elementary forms. They usually unite with each other in various proportions, and from the combinations thus formed, the plant obtains its nourishment.

Does it occur in the metallic state? With what is it found in combination? It is a constituent of what? What symbol represents aluminum? Its atomic weight? Is it found in the metallic form? When combined with oxygen, what is it a principle ingredient of? From what sources are the various elements supplied to the plant.

PART II.

PRIMARY COMPOUNDS.

The eighteen elementary substances described in the preceding pages, combine with each other in various proportions, forming a class of substances called *primary compounds.*

The following list contains all of these that are of interest to the agriculturist.

The column of *Symbols* shows what elements are united, and in what proportion, to form the different compounds. H O signifies the combination of Hydrogen and Oxygen. $N\,O_5$ represents the union of Nitrogen and Oxygen; the $_5$ indicating that there are five proportions or atoms of oxygen to one of nitrogen. There are five different compounds of these two elements—N O, $N\,O_2$, $N\,O_3$, $N\,O_4$, and $N\,O_5$, but none of them are of any importance connected with this department of chemistry, except the last. In the column marked *equivalents*, we have the combined atomic weights of the elements which form the compound. The atomic weights of oxygen and hydrogen are 8 and 1, therefore, when united to form *water*, the equivalent number is 9. In the compound, $N\,O_5$, we have one atom of Nitrogen—weight 14, and 5 atoms of Oxygen—weight $5\times8=40$; these numbers united give 54

Of what does Part II. treat? How are the *primary* compounds formed? What is the signification of H O in the table? Of $N\,O_5$? How are the five compounds of oxygen and nitrogen expressed symbolically? Whence are the numbers of the column marked *equivalent*, derived? Why is 9 the equivalent of water? Why is 54 the equivalent of nitric acid?

as the equivalent of Nitric Acid. This general law is observed with respect to the union of elements in different proportions. If an element combines with another to form different compounds, the number for that element in the higher combinations will be multiples of its number in the lowest.

Table of Primary Compounds.

Names.	Common Names.	Symbols.	
Protoxide of Hydrogen,	Water,	HO	9
Nitric Acid,	Aqua Fortis, [monia,	NO_5	54
Ammonia,	With water, Aqua Am-	NH_3	17
Carbonic Acid,	Fixed Air,	CO_2	22
Silica or Silicic Acid,	Flint, Sand, &c.	SiO_3	46
Sulphurous Acid,		SO_2	32
Sulphuric Acid,	Oil of Vitriol,	SO_3	40
Sulphuretted Hydrogen,		SH	17
Phosphoric Acid,		P_2O_5	72
Hydrochloric Acid,	Muriatic Acid,	HCl	37
Hydrofluoric Acid,		HF	19
Protoxide of Potassa,	Potash,	KO	48
Protoxide of Sodium,	Soda,	NaO	32
Chloride of Sodium,	Common Salt,	$NaCl$	60
Protoxide of Calcium,	Lime,	CaO	28
Chloride of Calcium,		$CaCl$	56
Fluoride of Calcium,	Fluor Spar,	CaF	38
Magnesia,		MgO	20
Protoxide of Iron,		FeO	36
Peroxide of Iron,	Iron Rust,	Fe_2O_3	80
Protoxide of Manganese,		MnO	36
Deutoxide of Manganese,	[ese,	Mn_2O_3	80
Per oxide of Manganese,	Black oxide of Mangan-	MnO_2	44
Alumina,	Clay, (impure)	Al_2O_3	52

NAMES.

It will be seen by referring to the table, that oxygen, in uniting with different elements, produces two kinds of compounds—*oxides* and *acids*.

The term *acid* signifies *sour* or *sharp*, and is applied to those compounds of a sour, biting character, which

What two classes of compound does *oxygen* form by its combinations?

have the power of changing most vegetable *blue* colors to *red.* If two acids are formed by the union of oxygen with one element, the name of the one which contains most oxygen, is formed by uniting the termination of *ic* to the name of that element that which has less by adding *ous* to the same. Thus sulphur*ic* acid has three proportions of oxygen, sulphur*ous* acid only two. Sometimes there are three acids, and in that case, the one which has least oxygen, forms its name by prefixing the syllable *hypo* to the name of the acid ending in ous: thus, we have another acid from sulphur and oxygen called hyposulphurous acid, containing one proportion of oxygen and one of sulphur.

The name *oxide* implies the union of oxygen with an element, but not in sufficient quantity to produce an acid. If there are several different oxides, the names are formed by prefixing the contracted Greek numerals, prot, deut and trit, signifying first, second and third. In this way we apply the name protoxide to the compound having the least oxygen, the compound containing an additional proportion of oxygen, is called deutoxide, &c. The term *peroxide* is usually applied to the compound containing most oxygen, whether it contain two, three, or four proportions. In the compounds of oxygen and nitrogen referred to, we have both oxides and acids.

Protoxide of Nitrogen,	$N\,O = 22$
Deutoxide of Nitrogen,	$N\,O_2 = 30$
Hyponitrous Acid,	$N\,O_3 = 38$
Nitrous Acid,	$N\,O_4 = 46$
Nitric Acid,	$N\,O_5 = 54$

What is the meaning of *acid,* and to what compound is this name applied? What is the rule for the terminations of the different acids? What does the name *oxide* signify? How are the names for different oxides formed? To what is the term *peroxide* applied? Name the different compounds of oxygen and nitrogen, and give their symbols and equivalents?

The word oxygen signifies *generator of acids*, and at the time this name was applied, oxygen was considered the universal acidifying principle. This was a mistake. It will be seen that two of the acids given in the table are formed without the aid of oxygen, as are others not given in this connection.

We shall now consider each of the primary compounds with its bearing upon the process of vegetation.

PROTOXIDE OF HYDROGEN, OR WATER.

$$H\,O=9.$$

We have already shown the properties of oxygen and hydrogen when examined separately. If these two gases be united in the proportions of two volumes of the latter to one of the former, or by weight, 1 of hydrogen to 8 of oxygen, a colorless liquid is produced with which all are familiar, under the name of *water*. This compound will not be formed by merely mixing the two gases in proper proportions. But if a lighted taper be applied to the mixture, the gases unite with a loud explosion, and water is the result.

Soap bubbles filled with this mixture, may be exploded while rising slowly through the air. In the explosion of the mixture of hydrogen and air, (p. 22,) water is produced by the union of the oxygen of the atmosphere with hydrogen. The same result is produced in the production of musical tones; the water accumulating upon the sides of the tube.

The elements of which water is composed exist in plants, forming from 35 to 50 per cent. of their weight.

What does the word *oxygen* signify? Is it the only generator of acids? What is the chemical name of *water?* What is the result when a mixture of oxygen and hydrogen is fired? To what extent do oxygen and hydrogen exist in plants?

Nearly all the hydrogen which plants contain, is supplied by the decomposition of water.

Most of the *oxygen* of the plant is without doubt, derived from the same compound, but this element may readily be obtained from several different sources.

These two elements, oxygen and hydrogen, do not exist in plants in just the proportions to form water, hydrogen being generally in excess.

All plants contain a quantity of water undecomposed. It forms $\frac{1}{2}$ by weight of all newly gathered vegetable substances, but is not taken into consideration in estimating the constituents of plants. Water has the power of dissolving solid substances, and absorbing gases, thus acting as a medium through which food is conveyed to the plant. In this way it acts a most important part in vegetation, and will be more fully treated of hereafter.

OF THE ATMOSPHERE.

Atmospheric air is a mixture of the gases oxygen and nitrogen, in the proportion by volume of 21 of the former to 79 of the latter. It contains other gases in very small quantity.

The constitution of air is found to be nearly the same in all places and at all heights above the surface of the earth. Gay Lussac experimented upon air brought down from a height of more than 21,000 feet, to which he had ascended in a balloon, but its constitution was identical with that of the air of lower regions.

The atmosphere terminates at a height from 40 to 50 miles above the surface of the earth. It is not neces-

---

Whence is obtained the hydrogen of plants? What else is derived mostly from the same source? How much water in newly gathered vegetables? What property has water that renders it very beneficial to the plant? What is the composition of atmospheric air? Is it the same in all localities? The height of the atmosphere?

sary to examine all the physical properties of air—its pressure—elasticity, &c., as they have no direct bearing upon this department of chemistry.

It is the oxygen of the air which renders it capable of supporting respiration, yet the nitrogen is required for the purpose of tempering or *reducing* the oxygen. If an animal be placed in an atmosphere of pure oxygen, the vital functions are excessively stimulated; the circulation of the blood is quickened, fever is induced, and the system is soon prostrated; nitrogen serves merely to *dilute* the oxygen.

Water has the power of absorbing the constituent gases of air, and it is possible that by this means these elements are conveyed into the circulation of plants, yet it is more probable that the oxygen and nitrogen of plants are derived from other sources. Atmospheric air is not a chemical compound, but a mere *mixture* of its constituent gases.

NITRIC ACID, OR AQUA FORTIS.

$N\,O_5 = 54.$

Although under ordinary circumstances, the oxygen and nitrogen of the atmosphere do not unite to form a chemical compound, yet whenever thunder showers occur, these elements are brought together and form nitric acid, (aqua fortis.) This acid carried to the soil unites with different substances, and sometimes forms extensive deposites of nitrogenous compounds. In this way a quantity of saltpetre is formed in the East Indies sufficient to supply all Europe.

Nitric acid is without doubt absorbed by the plant,

What would be the consequence were there no oxygen in the atmosphere? Are the oxygen and nitrogen of the plant derived from the atmosphere? Under what circumstances is nitric acid formed? Is it absorbed by the plant?

since it is found in the juices of many living vegetables. The tobacco plant contains it, probably in combination with potash. This will be indicated when the stalks of the plant are ignited; they will burn like paper that has been dipped in a solution of saltpetre.

Nitric acid applied to the young plant, greatly facilitates its growth, and the grain derived therefrom is usually nutritious in its quality. It is not applied in the acid form, but in combination with other substances. These compounds will be spoken of hereafter. Nitric acid is without doubt one source from which plants obtain the nitrogen which enters into their constitution, but as there is a very limited quantity of the acid formed in most soils, a supply of nitrogen must be ensured from other sources, one of the principal of which is the following compound.

AMMONIA.

$$NH_3=17.$$

Ammonia is a gaseous compound, consisting of nitrogen and hydrogen, united in the proportion of one atom of the former to three of the latter, $14+3=17$ the equivalent number for ammonia. If we pulverize sal-ammoniac, mix it with an equal quantity of slacked lime, and add water sufficient to form it into a paste; by applying heat, ammonia will be produced. It is a colorless gas, of an exceedingly pungent and irritating odor, and lighter than atmospheric air in the ratio of 59 to 100.

Water absorbs this gas with great avidity, especially at low temperatures. At the freezing point it takes up 780 times its own bulk. Thus dissolved in water, it

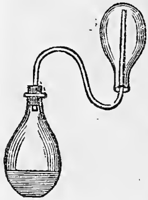
---

What proof? What is the effect of nitric acid upon vegetation? Is it applied in the acid form? What is said relative to the quantity of this acid in soils? How is ammonia obtained? How much of this gas does water absorb?

forms hartshorn or aqua ammonia. It was formerly obtained mostly from *horn*, and from this circumstance derives its name.

It is plain that in producing this gas, it can not be collected over water, as it would be absorbed by that fluid; but since it is much lighter than air, it can be collected in an inverted bottle or flask, as in (Fig. 13.)

Fig. 13.



Ammonia will not support combustion, but is itself in a slight degree combustible. It is given off in considerable quantity from decaying animal substances, and those vegetables which contain nitrogen give off ammonia in the process of decomposition. This gas is a source from which plants probably obtain both hydrogen and nitrogen, and is doubtless the *principal* source from which the latter is supplied to the plant.

Nitrogen, although forming but a small portion of the plant, is absolutely essential to the perfect development of the most important part of it, and since we are to depend principally upon ammonia for a supply of this element, it is of the first importance to the agriculturist to know in what way this gas is to be supplied to the plant.

It is exceedingly volatile, and if existing in the soil in an uncombined state, will soon pass off without benefiting the plant. It is brought down by every shower, having been absorbed by the rain from the atmosphere, and unless it is immediately united with some substance that has the power of retaining it or rendering it fixed, its volatility will cause it to disappear, and become again a part of the atmosphere.

What name is applied to water saturated with ammonia? How may this gas be collected? Whence is ammonia derived? What does it supply to the plant? Why is it important that this gas should be retained in the soil?

If nitric acid is formed at any time in the air, this probably unites with the ammonia, as will be shown hereafter.

Certain substances may be supplied to the soil that have the power of fixing volatile ammonia, and retaining it as food for the plant. Perhaps the most important of these is *charcoal.* We have before seen that this substance has the power of absorbing various vapors and gases; it absorbs ammonia to a greater extent than any other; one cubic inch of newly prepared charcoal absorbing ninety inches of the gas.

Ammonia is called an *alkali.* This term is applied to those compounds that have the power of neutralizing the different acids, restoring colors that have been changed to red by the same, and of changing some vegetable colors to green.

Not only is ammonia necessary for the purpose of supplying the elements of which it is composed to the plant, but it is believed to be itself, a constituent of vegetable forms; for it has been detected in the leaves of the tobacco plant and others; while some plants actually give off ammonia from their leaves or flowers. It is *probable* then that this gas is absorbed by the plant without decomposition, although this is by no means certain. Whatever the form may be in which it enters the plant, it is well determined that ammonia greatly facilitates the growth of vegetables. The following are some of Johnston's reasons for supposing that ammonia enters directly into the circulation of plants.

"It is proved, by long experience, that plants grow most rapidly and most luxuriantly when supplied with manure containing substances of animal origin. These substances are usually applied to the roots or leaves in

---

How may this be accomplished? What is said of the power of charcoal to absorb ammonia? Why is this gas called an *alkali?* What reason is there for believing that ammonia in its compound form is a constituent of plants?

a state of fermentation or decay, during which they always evolve ammonia. Putrid urine and night soil are rich in ammonia, and they are among the most efficacious of manures. This ammonia is *supposed* to enter into the circulation of plants along with the water absorbed by their roots, and sometimes even by the pores of their leaves. We can scarcely be said to have as yet obtained decisive proof that it does so enter, but probabilities are strongly in favor of this supposition; and when we consider minutely the mode in which it is like to act, when within the plant, we find the probabilities derived from practical experience to be strengthened by the deductions of theory."

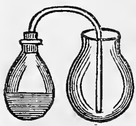
CARBONIC ACID.

$$C\ O_2 = 22.$$

When limestone is exposed to a high degree of heat, as in the lime-kiln, a colorless gas is given off which is called *carbonic acid.* It consists of one atom of carbon united with two of oxygen, and exhibits the properties of an acid, inasmuch as it changes certain vegetable blues to a red.

For experiment, it may be obtained from chalk by acting upon it in a glass flask or bottle, with oil of vitriol diluted with three or four parts of water. It may be collected over water as oxygen, &c., but on account of the power of water to absorb it, it is collected without the aid of this fluid. Carbonic acid is heavier than air in the ratio of 152 to 100; taking advantage of this property it may be collected in an open jar, as represented in the figure.

Fig. 14.



What are the views of Johnston? What symbol represents carbonic acid? What is its equivalent number? How may it be obtained? Collected?

On account of its great weight it can be poured from one vessel to another, and if a lighted candle be placed in a tumbler or small jar, and carbonic acid be poured from another vessel into this, the candle will be extinguished as if by magic. It is thus proved to be a non-supporter of combustion. Carbonic acid is disengaged in large quantities in some localities, and is always produced during the decay of vegetable substances. It is often exhaled from the ground, and accumulates in dry wells, vaults, and caverns. Persons have often lost their lives by entering wells, &c., which contained this gas. Before entering such places, a lighted candle should be lowered into the cavity; if it continues to burn, it is a certain indication of the absence of carbonic acid.

Eastern travelers relate that the existence of a cavern filled with this gas is a source of profit to some of the neighboring natives.

For the amusement of the stranger, a dog is thrown into the chasm; he soon falls down, to all appearance lifeless. The traveler pays for the dog and departs. The animal is immediately thrown into water and recovers; and in a short time is in a condition to *die again* for the benefit of his master and the amusement of travelers.

Even diluted with ten parts of air this gas is poisonous, and produces fatal effects if breathed. It is then pre-eminently a non-supporter of life. It is this gas that is given off from burning charcoal, and which has so often proved fatal to individuals warming small and tight rooms by means of coal. In this case the oxygen of the air unites with the carbon of which charcoal mostly consists, and produces carbonic acid which occupies

---

Describe the manner of extinguishing a candle with this gas. Under what circumstances is carbonic acid produced in nature? Where does it often collect? What precaution should be taken before entering vaults, caverns, &c.?

the space before occupied by the oxygen; thus we have an atmosphere made up of nitrogen and carbonic acid, both of which are hostile to animal life.

The process of respiration in a similar way converts the oxygen of the air into carbonic acid; the carbon being derived from the blood. This accounts for the change produced in blood by immersion in oxygen, (page 19.) The union of oxygen with the carbon of the blood produces just as much heat as the union of the same gas with carbon in the form of charcoal; hence the source of animal heat.

"The combination of a combustible substance with oxygen," says Liebig, "is, under all circumstances, the only source of animal heat. In whatever way carbon may combine with oxygen, the act of combination is accompanied by the disengagement of heat. It is indifferent whether this combination takes place rapidly or slowly, at a high or a low temperature; the amount of heat liberated is a constant quantity.

"The carbon of the food being converted into carbonic acid within the body, must give out exactly as much heat as if it had been directly burnt in oxygen gas or in common air; the only difference is, the production of the heat is diffused over unequal times. In oxygen gas the combustion of carbon is rapid, and the heat intense; in atmospheric air it burns slower and for a longer time, the temperature being lower, in the animal body the combination is still more gradual, and the heat is lower in proportion."

We have noticed three sources from which carbonic acid is given off into the atmosphere, combustion, respiration and the decay of vegetable substances.

Will carbonic acid support respiration? What gas is generated by burning charcoal? What changes are produced by the process of respiration? Will a pound of carbon withdrawn from the blood by respiration produce as much heat as a pound of the same element in the form of charcoal? What is the only source of animal heat? From what different sources is carbonic acid supplied to the atmosphere?

Since these operations have ever been going on and must continue as long as fires burn, animals breathe, and plants decay, we might reasonably suppose that the atmosphere would contain a considerable quantity of carbonic acid. By examination, it is found to contain a minute quantity, about $\frac{1}{2000}$ of its bulk of this gas. We have not noticed this in giving the constituent of air although it is a constant and all essential constituent.

It would be found in greater quantity in the atmosphere were it not that it is taken up by all growing vegetables, its carbon retained, and oxygen returned to the atmosphere. It is thus the great source whence is derived the *carbon* of the plant; this will be rendered evident by a few considerations.

In the first place, *carbon* being an insoluble solid, can not enter directly into the plant; it must first be changed to a liquid or gaseous form. By its union with oxygen it becomes a gas, which may be absorbed by water, and conveyed into the circulation of the plant through the root, or it may be absorbed by the water contained in the tissues of the plant.

If a spot of sterile land, impoverished by long tillage, and destitute of any vegetable matter, or carbon, be left undisturbed for a length of time, it will become covered with a growth of various kinds of grasses, weeds, shrubs, &c., year by year these die, fall to the earth, and become incorporated with the soil, while new shoots spring up growing more vigorously than the previous ones, and at length like them decay and mix with the earth. If this process continue a series of years, and then the land be cleared and broken up, it will exhibit a black fertile mould, and produce luxuriant

---

To what extent does it occur in air? Is it a constant constituent? Whence is derived most of the carbon of the plant? How is it conveyed into the circulation of the plant? What is the natural process by which sterile land frequently becomes productive?

crops, where all was barrenness. Whence was obtained the carbon of the first growth? for we supposed the soil destitute of *vegetable matter*,—the only *visible* depository of carbon that is available to the plant. It must have been obtained from the carbonic acid of the atmosphere. The second growth was more luxuriant than the first because it could obtain its carbon in part from the soil and because the vegetable matter mixed with the soil has the power of absorbing the different gases that nourish the plant. The accumulation of rich black vegetable mould, shows that notwithstanding a greater growth each succeeding year. Yet an excess of carbonaceous matter was annually deposited in the earth. It follows then, that whether the soil contain vegetable matter or not, the plant derives most of its carbon from the atmosphere.

Thus we learn that carbonic acid is the great supporter of *vegetable life* as oxygen to that of *animal.* Here we discover an instance of adaptation, of unity and design, in the natural world, that forcibly impresses us with the wisdom of that being who has made the "circle of eternal change" in the vegetable creation, serve to counterbalance the changes produced by animal existences, thus ensuring a happy equilibrium. Animals are continually vitiating the atmosphere—changing its oxygen to carbonic acid. Plants restore the equilibrium by absorbing the carbonic acid, retaining the carbon and returning the oxygen for the use of animals. In the beautiful language of Draper, "The carbonaceous matter which has flowed through the heart of man as blood, is transferred, by respiration to the air, and aids in the formation of forest trees or painted flowers. The Asiatics, with whom have originated all the varieties of pagan creeds that have spread to any ex-

---

If the soil contains a supply of carbonaceous matter will the plant still obtain most of its carbon from the atmosphere? By what succession of changes is the purity of the atmosphere preserved?

tent in the world, believed in a transmigration of souls; they would have been much nearer the truth had they believed in a transmigration of bodies. The coal that we burn is the remains of forests which, in former ages, were thronged with living things—forests that sprang, as do the trees with us, from gases that were formed from the respiration of animals—but of animals that are all extinct.

"Atmospheric air is the cradle of vegetable, and the coffin of animal life. Made up as it is, of atoms that have once lived, that have run through innumerable cycles of change, the aspect of purity it presents conceals too well its history. In its ethereal expanse are crowds of atomic forms that have once blossomed as flowers, or participated in the pleasures and pains of animal life." (*Chemistry of plants*, p. 11.)

SILICA, SILEX OR SILICIC ACID.

$Si\,O_3 = 46.$

When the element *silicon* is heated in the air, or in oxygen, it burns, and silicia—a compound of oxygen and silicon is the result. This compound exists in nature, completely pure in masses called quartz rock, and nearly pure in the various sandstones, sands, flints, &c., it constitutes a portion of most soils and of some a large portion; such are called *silicious* soils. Silica is infusible, and devoid of taste or smell, insoluble in water, and one of the hardest of minerals. It not only occurs in the mass in the sandstones of the earth's crust, but it forms by combination with other substances, various minerals that occur in different rocks.

Silica is found in the ashes of plants in great quantity,

Give the symbol and atomic weight of silica. Where does it exist in a state of purity? What are those soils called that contain it in large quantity? What are its properties?

but on account of its insolubility can not be taken up by them unless it first combine with other substances. Of these combinations we shall speak hereafter; deferring any farther remarks upon silica until that time.

SULPHUROUS ACID.

$$S\,O_2 = 32.$$

By burning sulphur in the air or in oxygen, white fumes are produced, intensely suffocating, and destructive of animal and vegetable life; this gaseous compound is sulphurous acid.

SULPHURIC ACID, OR OIL OF VITRIOL.

$$S\,O_3 = 40.$$

Sulphurous acid is changed to sulphuric acid by the following process. Into a leaden chamber containing a small portion of water, the fumes of burning sulphur are introduced, in connection with those arising from the decomposition of nitre,—nitrous acid fumes. The last serve as a medium through which oxygen is transferred from the air to the sulphurous acid, forming an oily fluid, which was once named *oil of vitriol*, but the scientific name for which is sulphuric acid. This acid may be obtained from green vitriol, by first depriving it of its water by exposure to heat, and then distilling it from a stoneware retort at a high heat. Obtained by either of these processes it is not pure sulphuric acid, but has combined with it a portion of water. By distilling the fluid obtained by the last process, a beautiful white crystaline substance is obtained which is the dry,

---

Why cannot pure silica be taken up by the plant? How is sulphurous acid produced? Of what is it composed? Give its equivalent number. How is this compound changed to sulphuric acid? How is oil of vitriol obtained from green vitriol? How may dry sulphuric acid be obtained?

pure sulphuric acid. It has a great affinity for water, and when thrown into it, hisses like red hot iron. The common sulphuric acid has a great avidity for moisture also; and if a portion be left open to the air it will absorb water to such a degree as to double its weight to the detriment of its quality. It is exceedingly sour and corrosive, nearly colorless when pure, but when any vegetable substance has been introduced, the acid chars it and becomes discolored.

Sulphuric acid seldom occurs uncombined; it is said to be contained in small quantity in streams in the vicinity of volcanoes. This acid is not generally applied to soils in its uncombined state. A few successful experiments have been made however, in which the acid was applied in a very diluted state. It occurs combined in certain mineral substances, especially in gypsum or plaster. Of these compounds we shall speak hereafter.

SULPHURETTED HYDROGEN.

$$S\ H = 17.$$

This gas is readily procured by acting upon the *sulphuret of antimony* (usually called *antimony*,) with hot muriatic acid, in a glass flask. It may be burned from a jet as it is formed, as represented in (Fig. 15.) This gas is given off in great quantities from some mineral springs, and is sometimes used in such localities for the purpose of illumination. Cold water absorbs it in considerable quantity, therefore in collecting it the water must be warmed or saturated with salt.

Fig. 15.

Sulphuretted hydrogen is distinguished by its un-

What is said of its affinity for water? Will sulphuric acid retain its strength if left open to the air? Describe its appearance and properties. Is it ever applied to soils? How is sulphuretted hydrogen procured? Where is it formed in nature? For what purposes is it sometimes used?

pleasant odor. It is this gas that gives to rotten eggs their disagreeable smell. With regard to its effect upon vegetation, &c., Johnston says: "Sulphuretted hydrogen is exceedingly noxious to animal and vegetable life, when diffused in any considerable quantity through the air, by which they are surrounded. The luxuriance of the vegetation in the neighborhood of sulphurous springs, however, has given reason to believe that water impregnated with this gas may act in a beneficial manner when it is placed within reach of the roots of plants. It seems also to be ascertained that natural or artificial waters that have a sulphurous taste, give birth to a peculiarly luxuriant vegetation, when they are employed in the irrigation of meadows."

PHOSPHORIC ACID.

$$P_2\,O_5 = 72$$

In the process given for obtaining nitrogen, (page 24,) the phosphorus unites with the oxygen of the air, in the jar producing white fumes. The new compound is phosphoric acid, which soon disappears on account of its affinity for water. If phosphorus is burned in dry air or oxygen gas, this acid is produced in the form of snow white flakes. If in this state it be thrown into water, it hisses as does dry sulphuric acid under the same circumstances. This acid exists in several compounds hereafter to be described, but does not occur in a free state, and therefore is not *directly* concerned in vegetation, in the acid form.

What does Johnston say with reference to its effect upon vegetation? Why is the chemical *equivalent* of phosphoric acid 72? How is this compound obtained? What is the effect of throwing the dry acid into water? Is phosphoric acid found uncombined in nature?

HYDROCHLORIC ACID, OR MURIATIC ACID.

$H\,Cl = 37.$

If we mix equal proportions of the two gases, hydrogen and chlorine, and expose the mixture to the light, the elements will unite and form a gaseous compound called hydrochloric acid. If the light be diffuse they combine slowly, but if bright sunlight be thrown by means of a mirror, upon a glass flask containing the mixture, the combination is instantaneous, accompanied by an explosion. In this experiment the flask should be covered with wire gauze. This compound is absorbed by water in large quantities, and the common name of the solution is *muriatic acid*, or *spirit of sea salt.* The gas can be obtained in a simpler way by the following process. Place in a flask three parts of common salt and five parts of sulphuric acid, (oil of vitriol.) As the acid is rapidly generated, it may be conducted by a bent tube into a vessel containing three parts of water, this will absorb the gas and form a solution of hydrochloric acid, which is the muriatic acid of commerce.

The gas when pure, is transparent and colorless; heavier than atmospheric air in nearly the ratio of 13 to 10. With regard to its influence when applied to soils, Johnston uses the following language.

" When applied to living vegetables in the state of an exceedingly dilute solution in water, it has been supposed upon some soils, and in some circumstances, to be favorable to vegetation. Long experience, however, on the banks of the Tyne, and elsewhere, in the neigh-

---

What other name for muriatic acid? Is formed by the combination of what elements? How are they made to combine? What is the equivalent of this acid? Is it a liquid or a gas? How is the liquid hydrochloric acid obtained? Describe the process for manufacturing the muriatic acid of commerce?

borhood of the so called alkali works, has proved that in the state of vapor its repeated application, even when diluted with much air, is often fatal to vegetable life.

Poured in a liquid state upon *fallow* land, or land preparing for a crop, it may assist the growth of the future grain, by previously forming, with the ingredients of the soil, some of those compounds which have been occasionally applied as manures."

HYDROFLUORIC ACID.

$HF=19$.

When speaking of fluorine, it was stated that this element had never been obtained in its uncombined state. The simplest form in which it has been obtained, is that of its combination with hydrogen, forming hydrofluoric acid. This compound is derived from a mineral called fluor spar. When this is pulverized and distilled in a leaden vessel with twice its weight of oil of vitriol, a colorless liquid heavier than water is obtained, very corrosive, and possessing the remarkable property of acting upon glass. This property is best illustrated by coating a piece of glass with a film of bees wax, and writing or sketching some picture in the coating. This is to be laid over a flat leaden vessel containing the mixture of fluor spar and sulphuric acid. Wherever the wax has been removed, the glass will be deeply etched. Hydrofluoric acid has recently been detected in the ashes of plants.

PROTOXIDE OF POTASSIUM, POTASSA, OR POTASH.

$KO=48$.

When the metal potassium is thrown upon water, decomposition ensues; the metal burns with a beautiful

---

What is said of the influence of this acid upon vegetation? From what is hydrofluoric acid obtained? Give the process. What remarkable property does this acid possess? How may glass be etched by it?

pink flame. The oxygen of the water unites rapidly with the metal forming protoxide of potassium, and the heat produced by the combination sets fire to the hydrogen evolved. The compound formed is commonly called potash; at the close of the experiment the fused globule of potash unites explosively with the water. It is very difficult to obtain potash perfectly free from water, but when in this state it is said to be *anhydrous*, (destitute of water.) When combined with water it is said to be *hydrated*, (containing water,) and the chemical name of potash in this state, is *hydrated oxide of potassium*. Potash may be obtained by the following process. Dissolve one part *pearl ashes*, or better, *sal tartar* in twelve parts of water: boil the solution and add while boiling one part of slacked lime, made into a cream with hot water; this should be added by degrees. The air should be excluded from the vessel by means of a tight lid, while the contents are cooling. After the lime has settled, the clear liquid is drawn off by means of a syphon, and this must be evaporated until it will consolidate in cooling; the potash in this state may be cast into the form of cylinders—the form of the caustic potash of the shops. Potassa in this form is a white solid, but absorbs moisture from the air and soon becomes liquid, unless kept in well stopped bottles. It acts energetically upon animal and vegetable substances, decomposing and dissolving them. Potash is an *alkali*, neutralizing the strongest acids, restoring the colors that have been changed to red by an acid, and changing some vegetable colors to green—as infusion of red cabbage. Since the potash of commerce is derived from the ashes of plants, it follows that it must be

---

What is the chemical equivalent of potassa? What compound is formed by throwing potassium upon water? What term is applied to potassa when free from water? When it contains water what is it called? Give the process for obtaining potash. What are the properties of potash? From what source is the potash of commerce derived?

a constituent of plants and of the soils upon which they grow, and without doubt acts an important part in vegetation. Potash does not occur in nature, however in its caustic state, but in combination with carbonic acid, &c., forming compounds of which we shall speak hereafter. Caustic potash is supposed to be formed, in small quantity, in compost heaps, from the compounds of potash contained therein, and by its decomposing power to render the vegetable matter soluble; fitting it for supplying nourishment to the plant.

PROTOXIDE OF SODIUM, OR SODA.

$$Na\,O=32.$$

The metal sodium when thrown upon water, decomposes it rapidly, and if prevented from moving about upon the water, will take fire, like potassium. Hydrated protoxide of sodium or caustic soda is the result. Soda may be obtained from the commercial carbonate of soda by the same process as that given for caustic potash, and closely resembles the latter in all its properties. It is a constituent of soils and plants, but always occurs in a state of combination. Common salt in compost heaps is sometimes converted into caustic soda, and in this form prepares the vegetable matter to be taken up by the plant. Soda is an alkali.

CHLORIDE OF SODIUM, OR COMMON SALT.

$$Cl\,Na=60.$$

Common salt, so familiar to all, exists very abundantly in nature, in the waters of the sea, and in the mineral

---

Is it a constituent of plants and soils? Give the composition and equivalent number of soda. How may caustic soda be procured? Its properties? From what is it sometimes formed in compost heaps? Where is common salt found?

crust of the earth, forming deposits of *rock salt*, and in saline springs which probably obtain their salt from such deposits. It is a compound of the gas chlorine with the metal sodium; most of its properties are known to all. It may be detected in the ashes of all plants, and in nearly all soils. "It is well known that common salt has been employed in all ages and all countries for the purpose of promoting vegetation, and in no country perhaps, in larger quantities than in England. That it has often failed to benefit the land in particular localities, only shows that the soil in those places already contained a natural supply of this compound large enough to meet the wants of the crops which grew upon it."—(Johnston.) Salt has been highly recommended by some and denounced by others, and men are more likely to remember a failure than a successful experiment. But a few months since a report was given by the committee on agriculture of the New York Legislature, in which some statements were made, showing the effects of salt as a manure. This induced some farmers to try the virtue of it upon their own soils. Some were disappointed, and probably concluded that it is useless as a fertilizer, but in hazarding such experiments it must be remembered that a difference of soil is sufficient to account for all such failures. If the character of the soil upon which salt has acted favorably, is definitely known, and the crop which was benefited by its action be known also, there can scarcely be a chance of failure in applying salt to the same crop on a similar soil.

Has it ever been employed as a fertilizer? With what success? Why has it failed in particular localities?

PROTOXIDE OF CALCIUM, OR LIME.

$Ca\ O=28.$

If the metal calcium be thrown into water, it decomposes this liquid as do potassium and sodium; taking up the oxygen and liberating hydrogen; the compound formed is the protoxide of calcium. If this combination is produced without the presence of water there is formed a white substance, known as quicklime or lime. If water be present, a hydrate of lime is formed, (slacked lime) containing about $\frac{1}{4}$ of its weight of this liquid. Quicklime is usually obtained for agricultural and other purposes, from the common limestone that forms so great a share of the rock formations of the earth's surface. This rock is subjected to an intense heat, until it loses about 44 per cent. of its weight, leaving nearly pure lime.

The union of water with lime, produces a great degree of heat—sufficient to fire wood, and inflame gunpowder. Lime is slightly soluble in water, and its solution is somewhat caustic and alkaline. It occurs extensively diffused, forming a share, and in many cases a large share of the different soils, and a large part of some mineral masses. It also occurs in the ashes of plants, and in the bones of animals, but in none of these positions does it occur in an uncombined form. Lime is frequently applied to soils, and with marked effect.

It not only exerts a beneficial influence in vegetation by supplying food to the plant directly from its own substance, but it seems to have the power of working

---

What is the chemical name of lime? What is its composition? When combined with water what is formed? Whence is quicklime usually obtained? Mention its properties. Where does it occur? In what manner does lime act favorably upon vegetation? What is its effect upon different soils?

changes in other compounds, and thus prepares them for becoming nourishment for the plant. By mixture with soils of a stiff clayey nature, it renders them porous and thus mechanically improves them. Upon soils of a light sandy nature however, the same effect only renders them more unproductive, yet lime may be applied to light soils with good effect, if accompanied by other substances. In connection with vegetable matter in almost any form it renders such soils fertile, but should never be applied to them unmixed with vegetable manures—the reason will be given hereafter. The question naturally arises, "In what form should lime be applied, in that of *hydrate*, or should it be unslacked?" If it be the object of the agriculturalist to extirpate useless weeds and grasses, or to decompose rapidly the different kinds of vegetable matter in the soil, it should be applied fresh from the kiln in its caustic, unslacked state. But when it is applied for the purpose of stimulating the growth of tender herbage, it should first be permitted to slack spontaneously, lest it act too energetically upon the young plant. In many cases it is immaterial in what form it may be applied. Lime should be applied, generally, sometime before the crop to be benefited is sown. If clover is to be ploughed in, or green sward to be broken up, it is better to apply the lime upon the surface before ploughing. To explain the various changes produced by lime, it will be necessary to treat of many compounds not yet described, we therefore omit the farther consideration of the subject in this connection.

With what should it be mixed before it is applied to light soils? When should it be applied in its unslacked form? When should the *hydrate* be applied? In what cases should it be applied before ploughing?

CHLORIDE OF CALCIUM.

$Ca\ Cl=56$.

This compound of chlorine and calcium, may be formed by dissolving chalk in hydrochloric (muriatic) acid, and evaporating the solution until it will crystalize in cooling. In this state it has two proportions of water,—called *water of crystalization.* It may be rendered *anhydrous* by exposing it to a red heat. In this form it is a white solid, phosphorescent in the dark, and having so great an affinity for water, that if exposed to the air, it rapidly absorbs moisture and changes to the liquid form. Compounds that possess this property of absorbing water and becoming liquid, are said to be *deliquescent.* Not only are the elements of this compound found in plants, but chloride of calcium itself has been detected in the sap. It would seem then that if it could be easily obtained, it might be very beneficially applied to the plant. With regard to the sources from which it may be obtained, and the effect of its application, Johnston makes the following statements.

"In reference to the culture of potatoes, I will here bring under your notice the chloride of calcium, which is said to have been beneficially applied to various crops, to potatoes especially, with surprising effect. Under the influence of this substance, the sunflower and maize have grown to the height of 14 to 18 feet, and potatoes have attained the weight of 2 to 3 pounds. This compound occurs in sea water, and is also contained largely, though mixed with other substances, in the mother liquor of the salt pans, and from the numerous salt works of the coast, might readily be obtained for trial."

How is chloride of calcium formed? What is said of its avidity for moisture? What term is applied to those compounds that become liquid by absorbing moisture?

FLUORIDE OF CALCIUM, OR FLUOR SPAR.

$CaF=38.$

Fluor Spar, the mineral from which hydrofluoric acid is obtained, (see page 52) is a compound of fluorine and calcium. The same compound is found in small quantity in the bones of animals, and since the substance of all animal forms must have been derived from their food, it seems a necessary inference that plants must contain this compound. It has been detected in the ashes of plants, in minute quantity, but probably does not exert a very important influence upon vegetation.

PROTOXIDE OF MAGNESIUM, OR MAGNESIA.

$Mg\ O=20$

Magnesium heated to redness in the open air burns brilliantly, and forms *magnesia* or the protoxide of magnesium; this is identical with the calcined magnesia of commerce. It is similar to lime in many of its properties and is sometimes found in limestones; such receive the name of magnesian limestones. The quicklime obtained from such rocks, when applied to land sometimes produces injurious effects, probably from the quantity employed. It has been suggested that it is owing to the compounds formed by the union of magnesia with noxious acids which exist in the soils. In this way salts are formed which are quite soluble in water, and are carried into the circulation of the plant.

It should be borne in mind, however, that this com-

What is said of the effect of fluoride of calcium upon vegetation? Give the chemical composition of fluor spar. Where is this compound found? Whence must it have been originally derived? Why is the combining number of magnesia 20? What is the effect of quicklime containing magnesia upon plants?

pound is a very essential ingredient of most plants, and therefore substances containing it in limited quantity, should be supplied to the soil.

OXIDES OF IRON.

Protoxide, $Fe\ O=36$. *Peroxide*, $Fe_2\ O_3=80$.

When iron is exposed to air and moisture, the surface becomes covered with a reddish brown substance, which is called *rust*; this is the peroxide of iron. It occurs very abundantly in soils, giving to them their red color. It not only supplies food to the plant from its own substance, but seems to have the power of absorbing ammonia, and retaining it as nourishment for the plant. If in connection with this oxide, there is a large quantity of vegetable matter in process of decomposition, the peroxide becomes changed to a protoxide, a part of the oxygen uniting with the carbon, to form carbonic acid. The protoxide readily combines with certain substances, and the compounds formed are mostly soluble in water, and in this way pass into the circulation of the plant, proving, in some cases, exceedingly injurious. If the soil, however, in which these noxious compounds occur be kept loose and porous, they will be decomposed by the action of the atmosphere and the protoxide again become a peroxide. Soils then which contain much oxide of iron, should be frequently broken up and exposed to the oxydizing action of the atmosphere.

Is magnesia a necessary element in vegetation? What oxide is found by exposing iron to air and moisture? Where does this oxide occur? What property does it possess by which it facilitates the growth of the plant? How is it converted into protoxide? In this form is it prejudicial to the plant. How may the protoxide in the soil be converted into a peroxide?

OXIDES OF MANGANESE.

Protoxide, $Mn\ O=36$. *Deutoxide*, $Mn_2\ O_3=80$.
Peroxide, $Mn\ O_2=44$.

The substance known as the *black oxide of manganese* is a compound of manganese and oxygen in the proportion of one atom of the former to two of the latter, and its equivalent number is 44, as given above. This compound is called the *peroxide*, and occurs abundantly in nature, very frequently combined with the various ores of iron. When exposed to heat, as in the experiment for obtaining oxygen, (page 21,) it abandons a portion of its oxygen and is changed to the *deutoxide*, $Mn_2\ O_3=80$. This compound also occurs in considerable quantity in nature, and resembles the peroxide in appearance. If the latter be heated to redness in a glass tube, and a stream of hydrogen be made to pass through it, the *protoxide* of manganese will be formed, a greenish gray substance. These oxides are insoluble in water, and therefore can not enter into the circulation of the plant without first forming soluble compounds with other substances contained in the soil.

OXIDE OF ALUMINUM, OR ALUMINA.

$Al_2\ O_3=52$.

The metal aluminum slowly decomposes boiling water, uniting with its oxygen to form alumina, and evolving the hydrogen. Pure alumina is a white solid, tasteless, and insoluble in water. Though it forms but a small

---

What is the chemical constitution of the peroxide of manganese? To what is it changed in the process for obtaining oxygen? How is the protoxide of manganese obtained? Why do not these oxides enter directly into the circulation of the plant? What is the effect of aluminum upon boiling water? What are the properties of alumina?

proportion of the plant, it seems to act indirectly in facilitating the growth of vegetable forms. This compound is the principal ingredient in all clays. Burned clay when applied to soils has proved very beneficial. This effect is undoubtedly due to the property of absorbing ammonia which alumina possesses. That clay retains ammonia may be shown by moistening it with a solution of caustic potash, or by mixing quicklime with it and moistening the mixture; in either case ammonia will be evolved, and may be made apparent by holding over the mixture a feather dipped in vinegar or muriatic acid, when white fumes will be formed by the union of the ammonia and acid.

Nearly pure alumina may be obtained from alum by dissolving in water, and adding a solution of pearlash as long as a white precipitate is produced. This white substance must be separated by filtering, washed and dried. This substance is found nearly pure in some of the rarer minerals, and impure in the slates and shales of the crust of the earth; it is an ingredient in most soils, giving them tenacity and rendering them retentive of moisture. If it exists in too great proportion, it renders a soil cold and wet from its being impervious to water.

The primary compounds have now been treated of separately, but it will be noticed that some of them are not found in soils or plants uncombined. It will be necessary therefore, to treat of the secondary compounds formed by the union of the primary with each other. The different elements of the plant are for the most part derived from these compounds.

It is the principal ingredient of what? To what is the favorable action of burned clay upon vegetation owing? How may it be shown that clay retains ammonia? How may alumina be obtained in a nearly pure form? What is the effect of alumina upon soils? Do the primary compounds generally occur in the soil uncombined with each other?

PART III.

SECONDARY COMPOUNDS.

NAMES.

By examining the table of primary compounds (page 34,) it will be seen that nearly all the *acids* given, are formed by the union of oxygen with the *non-metallic* elements. The combination of oxygen with the metallic elements, generally in one proportion, forms a class of compounds called *bases*. Oxygen in some cases, unites with a metal in one proportion forming a *base*, and in other proportions forming an *acid*, or perhaps more acids than one. Thus we have the protoxide of manganese as a base, but manganese uniting with three proportions of oxygen forms *manganic acid*. Potassa, soda, lime, protoxide of iron, protoxide of manganese, &c., are *bases*. *Acids* combine with *bases* to form a class of secondary compounds called *salts*. Ammonia, formed by the union of two non-metallic elements, is also a base, and forms salts by combination with the different acids.

In examining the secondary compounds, we shall take up the first *base* in the list, and consider its combinations with the several acids.

We give below a list of these compounds, beginning with ammonia as a *base*. The following rules are observed in giving names to these compounds. If the name of the acid ends in *ic*, that termination is changed

---

How are most of the acids formed? How are bases formed? What do the combination of acids and bases produce?

to *ate*, and the word thus changed, united with the name of the base, forms the name of the compound. Nitric acid uniting with soda forms a nitr*ate* of soda, sulphuric acid with the same base, a sulph*ate* of soda. If the acid ends in *ous*, that termination is changed to *ite* in giving the name of the salt. Thus, sulphurous acid forms sulph*ites* of the several bases.

In the column of symbols it will be noticed that the salts of ammonia are not represented by the combination of the symbols of the acid and base, as we might at first expect, for instance, we have for nitrate of ammonia, $N O_5 + N H_4 O$ instead of $N O_5 + N H_3$. There is a hypothetical compound of a metallic nature, called ammonium, containing one proportion of hydrogen more than ammonia contains, and its symbol is $N H_4$ or merely Am. It has been produced in connection with other metals, but has never been separated from them: it is therefore called a hypothetical compound. In the formation of the nitrate, sulphate, and carbonate of ammonia, this metal in the form of an *oxide* unites with the several acids.

According to this view, the *base* ammonia like other bases, is formed by the union of oxygen with a metal.

The symbols and equivalents of certain compounds are omitted, because it would be unprofitable here to go into an explanation of them. The compound called muriate of ammonia is perhaps strictly speaking, a *chloride of ammonium*, and its symbol $Cl N H_4$ or Cl Am, but the elements combined are the same whether it be considered one way or the other.

Certain of the salts contain a portion of water called water of crystalization; thus, the sulphate of iron in its

When the name of the acid ends in *ic*, how is the name of the salt formed? How when the acid ends in *ous?* What is the constitution of ammonium? In what form does this metal unite with the acids? What is said of muriate of ammonia?

crystalized form contains seven proportions of water, its symbol therefore, would be $SO_3+FeO+7 Aq$, (Aq signifying water,) and its equivalent 139. The symbol given in the table will apply only to the sulphate after it has been deprived of its water by heat. In the symbols of several other compounds, the water which they usually contain is not indicated.

Table of Secondary Compounds.

Names.	Common Names.	Symbols.	Equiv.
Nitrate of Ammonia,		NO_5+NH_4O	80
Carbonate "		CO_2+NH_4O	48
Sulphate "		SO_3+NH_4O	66
Phosphate "			
Muriate "	Sal Ammoniac,	$HCl+NH_3$	54
Nitrate of Potassa,	Nitre, Saltpetre,	NO_5+KO	102
Carbonate "	Sal tartar, Pearlash	CO_2+KO	70
Silicate "			
Sulphate "		SO_3+KO	88
Nitrate of Soda,		NO_5+NaO	86
Carbonate "		CO_2+NaO	54
Silicate "			
Sulphate "	Glauber's Salt,	SO_3+NaO	72
Nitrate of Lime,		NO_5+CaO	82
Carbonate "	Chalk, Limestone,	CO_2+CaO	50
Silicate "			
Sulphate "	Gypsum, Plaster,	SO_3+CaO	68
Phosphate "			
Nitrate of Magnesia,		NO_5+MgO	74
Carbonate "		CO_2+MgO	42
Silicate "			
Sulphate "	Epsom Salts,	SO_3+MgO	60
Sulphate of Iron,	Copperas,	SO_3+FeO	76
Carbonate "		CO_2+FeO	58
Sulphate of Manganese,		SO_3+MnO	76
Silicate of Alumina,			

How many proportions of water does the sulphate of iron contain? To what does its symbol given in the table apply?

NITRATE OF AMMONIA.

$$NO_5+NH_4O=80.$$

Ammonia added to nitric acid neutralizes its acid properties, and by evaporation a *deliquescent* salt is obtained, called the nitrate of ammonia. We have mentioned before the formation of nitric acid during thunder showers; this acid so formed, unites with the ammonia that is ever present in the atmosphere, and forms *nitrate of ammonia.*

We may here state that it is supposed by some, and with reason, that in the formation of nitric acid under the circumstances mentioned, the nitrogen is derived from ammonia, rather than from the constituents of the atmosphere. When the nitrate is brought to the earth it is soon decomposed, the nitric acid forms other nitrates in the soil, of which we shall speak hereafter, and the ammonia is set free, passing into the atmosphere or perhaps in part into the circulation of the plant. The nitric acid is thus retained in the soil, and acts beneficially upon the plant.

An instance of the effect of nitrate of ammonia as a manure is given by Petzholdt. A meadow which without manure produced 8,000 lbs. of hay, after the application of this salt, yielded 11,200.

CARBONATE OF AMMONIA, OR VOLATILE SALTS.

$$CO_2+NH_4O=48.$$

If we arrange a flask containing the materials necessary for generating ammonia, (see page 39) and another supplied with the substances used for producing carbonic acid, (page 42) and cause the gases to be convey-

---

How is nitrate of ammonia formed? How is it formed in nature? Will nitrate of ammonia remain fixed in the soil? What instance is given of the nitrate of ammonia as a manure? How may the carbonate of ammonia be formed? What is the common name of this compound?

ed into the same receiver, an incrustation of *carbonate of ammonia* will be formed upon the receiving vessel. This salt has the pungent odor of ammonia, but it is not the common *sal volatile* of commerce; this compound is usually obtained by exposing a mixture of powdered chalk and sal ammoniac to a high heat in an earthern retort. The salt forms a crust upon the inside of the receiver. This form of the carbonate is not a simple salt, but a mixture of two, because by washing with water or alcohol we have remaining the *bi-carbonate* of ammonia (the prefix *bi* signifying that they are two proportions of carbonic acid,) and that which is washed out is the carbonate. There are other salts formed by the union of carbonic acid with ammonia, but in treating of their influence upon vegetation, we shall use the term *carbonate of ammonia* merely, without reference to the more complex compounds.

We have before spoken of the sources from which the gas ammonia is supplied to the air and of the favorable influence it exerts upon vegetation. When it is given off from the soil, the compost heap, or from decaying substances, it generally unites immedtately with carbonic acid, these gases being often generated simultaneously in the decomposition of different substances; but when ammonia does not unite with this acid immediately, it passes into the atmosphere, and coming in contact with the carbonic acid of the air, unites with it. The carbonate thus formed is brought down in greater or less quantity, by every shower. We have seen before that, under certain circumstances, nitrate of ammonia will be formed, but nitric acid is not usually contained in the atmosphere, whilst carbonic acid is a constant constituent. It follows then, that ammonia will be usually converted into a carbonate.

How is it usually obtained? How may it be shown that the common form of the carbonate consists of two salts? What is the signification of bi-carbonate? With what does ammonia usually combine as it is formed?

The carbonate of ammonia, by decomposing compounds contained in the soil or compost heap, often exerts a more beneficial influence upon vegetation than ammonia uncombined with an acid. It decomposes gypsum or plaster, as will be shown hereafter when treating of that compound. Ammonia, it will be recollected, is a compound of hydrogen and nitrogen, and from this compound the plant probably obtains both of these elements; but hydrogen may be supplied from other sources, whilst the agriculturalist must depend almost wholly upon ammonia or its compounds for a supply of nitrogen; and since ammonia either uncombined or in the form of a carbonate is volatile, and will not remain fixed in the soil, it is of the first importance that we should ascertain some method by which it may be retained, so that its nitrogen may be assimmilated by the plant. There are certain compounds, soon to be examined, that are chiefly beneficial on account of their power of *fixing* in the soil the volatile ammonia of the atmosphere.

SULPHATE OF AMMONIA.

$$SO_3+NH_4O=66.$$

If the acid properties of oil of vitriol be neutralized by adding carbonate of ammonia, the acid, by its combination with ammonia forms a salt, and carbonic acid is set free. The compound formed is the sulphate of ammonia. It crystalizes, holding in combination one proportion of water, and is never obtained free from it. The proper symbol then for it is SO_3+NH_4O+Aq.

Sulphate of ammonia is a valuable fertilizer, since it

In what way does carbonate of ammonia exert a favorable influence upon vegetation? What does ammonia supply to the plant? Will ammonia, either uncombined or in the form of carbonate, remain fixed in the soil? Of what is sulphate of ammonia formed?

supplies two important substances to the plant, ammonia and sulphuric acid, yet, this salt can seldom be applied economically to the soil. It may be formed however by the agriculturalist by neutralizing the ammonia which is contained in liquid manures, by means of oil of vitriol, and thus this volatile gas is retained in a form suited to the wants of the plant. If the liquid excrements of men and animals be preserved and neutralized by sulphuric acid, the sulphate of ammonia produced, will form, with the other compounds contained by such fluids, an exceedingly rich manure.

The following statement by Petzholdt shows the value of this ammoniacal salt as a fertilizer.

"From a meadow which had not been manured 8000 lbs. of hay were obtained, after the use of sulphate of ammonia as manure, the same surface yielded 10,466 lbs., being 2, 466 more."

PHOSPHATE OF AMMONIA.

This compound of phosphoric acid and ammonia is detected in human urine and guano, and is a very important constituent of such manures. It will be seen hereafter that the ashes of the *grains* of wheat contain nearly fifty per cent. of phosphoric acid, rye about forty-seven, &c. The effect then of phosphate of ammonia upon vegetation might be inferred without recourse to experiment; and the same is true of other phosphates. The richest manures owe their fertilizing qualities to the presence of compounds of phosphoric acid with ammonia, lime, soda, magnesia, &c.

What does sulphate of ammonia supply to the plant? How may sulphate of ammonia be formed by the agriculturist? Give an instance of the effect of this compound as a manure? What important compound is contained by guano, &c.? How extensively does it occur in the grains of wheat and rye? What is said of the fertilizing qualities of the richest manures?

MURIATE OF AMMONIA, OR SAL AMMONIAC.

$$HCl+NH_3=54.$$

Sal ammoniac, a compound known to all, is formed whenever ammonia and muriatic acid gas are permitted to mingle. If the two gases be passed into a receiver, they will combine and form pure muriate of ammonia in the form of snow white powder. The commercial sal ammoniac is formed by neutralizing ammoniacal liquors, obtained by the destructive distillation of horns and bones, with common muriate acid, and evaporating until the liquid will crystalize in cooling. The more scientific name of this compound is *hydrochlorate* of ammonia, since the proper name of the acid is *hydrochloric*, and not *muriatic*. Its action as a fertilizer is like that of the sulphate of ammonia, but perhaps more marked, and the agriculturalist can form the compound by saturating the liquid manures containing ammonia, with muriatic acid. By this means the ammonia is rendered non-volatile, and will not escape into the atmosphere after being applied to the soil. It is stated by Petzholdt that a meadow which without manure produced 8,000 pounds of hay, after the application of hydrochlorate of ammonia yielded 11,432 pounds, an increase of 3,432 pounds.

A solution of muriate of ammonia is sometimes used for soaking seeds before they are deposited in the ground; when thus treated the seed is said to sprout sooner, and the young plant to grow more vigorously.

How is muriate of ammonia formed? What are the different names for this compound? Give the statement of Petzholdt? What is the effect of sal ammoniac upon seeds?

NITRATE OF POTASH, SALTPETRE, OR NITRE.

$$N\,C_5 + K\,O = 102.$$

Nitre may be formed by uniting nitric acid with potash, or its carbonate and evaporating until it crystallizes. The nitre of commerce is derived mostly from certain soils, called *salt petre grounds*, in which either the nitre is found ready formed, and can be obtained by merely lixiviating the soil, or nitrate of lime is contained, which can be easily decomposed by carbonate of potash so as to form the nitrate. The soils in which nitre occurs generally contain animal and vegetable matter, and artificial nitre beds may be formed by mixing animal and vegetable substances with lime, ashes and earth. It is a question whether the elements of the atmosphere are made to combine by electrical agencies, to form the nitric acid of the nitrates in the soil, or whether the nitrogen arising from the decomposition of animal and vegetable substances unites with the oxygen of the air to form the same.

Nitre is found in certain plants, and in the dried stems of some vegetable forms, even occurs in needle-form crystals. It is evident that this salt will act favorably upon such plants, and experiment has shown that when applied to the soil in proper quantity, it greatly promotes the growth and luxuriance of all crops. If present in the earth in excess, it is hostile to vegetable life, and renders the soil barren. The earth obtained from localities in which this compound accumulates; as the ruins of old buildings, the earth of cellars, stables and certain caves; may be profitably mixed with other manures to form valuable composts.

From what source is the nitre of commerce derived? How is it obtained? How may artificial nitre beds be formed? What is said of the existence of nitre in plants? What effect has nitre when applied to the soil? What the effect of large quantities? What is said of the earth, of cellars, stables, &c.?

CARBONATE OF POTASH, OR SALT OF TARTAR.

$$CO_2 + KO = 70.$$

Impure carbonate of potash may be procured by lixiviating wood ashes, and evaporating the liquid thus obtained. If this be dissolved in water, and the clear fluid drawn off and evaporated, another form of the carbonate is obtained called pearlash, but this form, too, is impure. Pure carbonate of potash is obtained by calcining cream of tartar, dissolving out the salt by means of water, and evaporating the liquid to dryness. This form is called *salt of tartar*. It is hardly necessary to say that carbonate of potash, in any form, exerts a powerful influence upon vegetation. Wood ashes have been employed for the purpose of increasing the fertility of the soil, in almost every country and from the earliest times, and their favorable action depends mostly upon the carbonate of potash contained. The action of this compound is much more favorable upon some crops than others, because it is contained in greater quantity by certain plants than by others.

When the importance of potash is considered—it being a necessary constituent of every fertile soil—it becomes a matter of surprise that the farmer should dispose of the ashes which he obtains by burning wood, at a price really far below their real worth; their value, however, does not depend merely upon the amount of potash contained, for besides this compound there may be found soda, lime, magnesia, silica, alumina, oxides of iron and manganese, sulphuric acid, phosphoric acid, &c. Wood ashes, even after they have been lixiviated

---

What is the chemical name of salt of tartar? How are the different forms of carbonate of potash obtained? What is said of the effect of the carbonate upon vegetation? Of the value of wood ashes? Are ashes valuable which have been deprived of their potash? Why?

and thus deprived of their potash, still contain many valuable ingredients, and may be advantageously applied to soils.

Ashes seem to have the power, not only of facilitating the growth of useful plants, but also of exterminating useless ones, for when applied to coarse grasses they disappear, and more tender and nutritious ones supply their place.

SILICATE OF POTASH.

Silica combines with potash in different proportions, forming *silicates*, but it is difficult to discover their exact chemical constitution, and therefore the symbol and chemical equivalent of the compound under consideration, are omitted.

The principal ingredients of glass are silica, potash, soda, and lime; when these are fused together, the silica unites with the others forming silicates. Potash and silica fused together, form a kind of glass, and if a considerable proportion of potash be used the compound will be soluble in water. This composition is called *liquor of flints.* Glass formed by fusing together 76 parts of fine white sand, 27 of dry carbonate of soda, and 35 of carbonate of potash, is soluble in water, and when the solution is applied to wood it is said to render it incombustible.

Silica in its uncombined form, it will be recollected, is insoluble in water; we infer therefore that it can not be assimilated by the plant, unless it be first combined with some substances to form soluble compounds. Potash and soda are the substances with which it usually unites. The insoluble silicates may be decomposed by

---

What is the effect of wood ashes upon coarse grasses? What is silicate of potash? What are the ingredients of glass? Soluble glass? Is silica soluble in water? What change must take place before it can be taken up by the plant? With what substances does it usually unite?

the carbonic acid of the air; indeed, this process of decomposition is continually going on wherever the silicates exist in the soil or in rocks, and the silica which is separated is slightly soluble in water, and considerably so in solutions of potash, soda, &c. We see then the importance of supplying silicates, either soluble or insoluble, to those soils which are destitute of them, or at least of supplying a sufficient quantity of potash to unite with the silica in the soil, and thus provide for the wants of the plant.

Wood ashes contain a certain portion of the silicates, and hence their favorable action upon plants that require much silica. Plants may be so classified as to indicate the compound predominent among their constituents. They are sometimes divided into three classes, *silica* plants, *lime* plants, and *potash* plants. Oats, barley, hay, &c. are silica plants, their ashes containing a large percentage of silica.

SULPHATE OF POTASH.

$$SO_3+KO=88.$$

This salt may be formed by the combination of sulphuric acid and potash, but the sulphate of commerce is produced by the decomposition of nitrate of potash by oil of vitriol in the manufacture of nitric acid. Sulphate of potash is a crystaline salt, and sparingly soluble in cold water. It exerts a favorable influence upon vegetation when supplied to the soil, but can not be economically applied in its pure form as a manure, on account of its high price. It occurs, however, in the ashes of wood, and in this form may be applied, in con-

---

How are the insoluble silicates decomposed? What should be supplied to soils? How may sulphate of potash be formed? What is the effect of sulphate of potash upon vegetation? Where is it found in connection with other substances?

nection with other substances. Its favorable action seems to depend upon the supply of sulphur and potash to the plant.

"Dissolved in 100 times its weight of water, the sulphate of potash has been found to act favorably on red clover, vetches, beans, peas, &c., and part of the effect of wood ashes on plants of this kind is to be attributed to the sulphate of potash they contain. Turf ashes are also said to contain this salt in variable quantity, and to this is ascribed their efficacy when applied to land." (Johnston.)

NITRATE OF SODA.

$$NO_5 + NaO = 86.$$

Nitrate of soda may be produced by the action of nitric acid upon carbonate of soda. It is sometimes formed in the soil in the same manner that the nitrates of potash and lime are, in the saltpetre grounds. Extensive deposites of this salt are found in Chili and Peru upon the surface, and from these localities much of the nitrate of soda of commerce is obtained. This salt is somewhat deliquescent and very soluble in water. Its action in promoting vegetation is quite similar to that of the nitrate of potash, since the nitric acid contained by each is principally concerned in hastening the growth of the plant. The soda and potash, however, are by no means unimportant. The nitrates of soda and potash have been applied in Europe with varied results. The following are the effects produced as given by Johnston.

"The first visible effect of the nitrates upon every crop

What elements does it supply to the plant? Give the substance of the statement of Johnston. How may the nitrate of soda be formed? Whence is much of the nitrate of soda of commerce derived? What is said of the nitric acid of the nitrates of potash and soda?

is to impart a dark green color to the leaves and stems.

2d. They hasten, increase, and not unfrequently prolong the growth of the plant.

3d. They *generally* cause an increase both in the weight of hay or straw, and of corn, though the color and growth are occasionally affected without any sensible increase of the crop.

4th. The hay or grass produced is always more greedily eaten by the cattle than that which has not been dressed, even when the quantity is not affected; but the grain is usually of inferior quality, bringing a somewhat less price in the market, and yielding a smaller produce of flour.

Its principal action seems to be expended in promoting the growth—that is, increasing the production of woody fibre, either in the stem or the ear, without so much affecting, except indirectly, the quantity of seed.

Mr. Pusey observed, that the increase of his wheat crop, on the Oxford clay, where nitrate of soda was applied, arose from there being *no underling straws with short ears* as in the undressed, but all were of equal length, and consequent fullness and ripeness. The nitrate had merely promoted the growth.

" It affected the tops of the *potatoes*, but the produce of bulbs was less both by weight and measure." (Mr. Grey, of Dilston.) "On peas, in a thin sandy soil, subsoil gravel, it had much effect on the color and strength of the stems, and on the state of forwardness, but when ripe, though the straw was stronger, there was no difference in the crop of peas." (Col. Campbell, of Roselle.) " On land in high condition it did harm by forcing the straw at the expense of the ear." (Mr. Barclay.) "It appeared to act strongly, and there was a greater bulk of straw, but the increase of grain was

---

State the different effects of the nitrates? Do the nitrates seem to increase the quantity of seed?

only 50 lbs. per acre." (Sir Robert Throckmorton.) In another experiment of Mr. Barclay's the straw was very strong, and much of the wheat laid, but the undressed sold for 4s. a bushel more, and there was no profit.

In all these cases the nitrate promoted chiefly the growth of the stem, or the production of woody fibre. The inferior quality of grain, and great yield of straw, was owing to this action. The grain was enveloped in a thicker covering of the woody matter which forms the skin or bran.

From the above statements we seem to derive an explanation why the effects of the nitrate should have been so universally observed upon the grasses and clovers—while in regard to its application to *corn crops*, they indicate this important—

Practical Rule.—Not to apply the nitrates upon land or under circumstances where there is already a sufficient tendency to produce straw.

Effect of the nitrates on the QUALITY *of the crop.*

It so affects the grass and clover as to make it more relished by the cattle. This is usually expressed by saying that the crop is *sweeter*, but since cattle are known to be fond of saline substances, it may be that the grasses are, by these salts, only rendered more savory. It generally also gives a grain (of wheat) of an inferior quality, which has a thicker skin, and yields more bran. This may possibly arise from its having been generally allowed to ripen too long. A question still undetermined is, whether the flour of nitrated corn is more nutritive than that obtained from corn which has been undressed."

What practical rule is deduced from the results of various experiments? State the effects of the nitrates upon the quality of the crop? What question is still undetermined?

CARBONATE OF SODA.

$$CO_2 + NaO = 54.$$

The appearance of carbonate of soda is familiar to all in the form of the common *soda* of commerce. When crystalized, it contains ten proportions of water, and its symbol would be $CO_2 + NaO + 10, Aq = 144$, but the crystaline carbonate, when exposed in dry air, *effloresces*, or loses its water of crystalization, and becomes a dry white powder. This salt is manufactured upon a large scale from common salt, (chloride of sodium.) It may be obtained also from the ashes of marine plants, as carbonate of potash is from those of land plants. The action of this salt as a fertilizer has been found favorable, especially upon certain plants. It is stated by Johnston, that the carbonates of potash and soda greatly hasten the growth of the *strawberry*, and by Sprengel, that the carbonate of soda assists in a remarkable manner the growth of buck-wheat. The presence of soda is essential to the perfection of the plant; the first effect of the carbonate therefore will be to supply a necessary constituent to the plant, but its action is by no means confined to this: it has much to do with preparing other substances to become food for the plant. By its action the vegetable matter in the soil becomes soluble, and is thus fitted to enter into the circulation of the plant. Carbonate of potash produces the same effect, but both of these compounds probably exert a more important influence by rendering soluble the silica and insoluble silicates of the soil. When speaking of the silicate of potash, the manner in which the insoluble

---

What is the chemical constitution of carbonate of soda? When crystalized what does it contain? From what is it usually obtained? What is its effect upon buck-wheat? What effect does it produce upon vegetable matter? What effect is produced by the carbonates of potash and soda upon silica, &c.?

compounds are rendered soluble, was pointed out. A solution of carbonate of soda in water has the same power of uniting with silica, or of decomposing insoluble silicates, producing the following compound.

SILICATE OF SODA.

This compound, in its properties and action upon vegetation, is quite similar to the silicate of potash. It has been seen that silica is totally insoluble in water, and therefore can not enter into the plant in its uncombined state. It is probable that nearly all of the silica of plants enters in the form of silicates of potash and soda, for the solutions of these salts in water slowly unite with silica, and form soluble compounds. Although the silicates have not been applied to any great extent as manures, except as they occur in small quantities in wood ashes; yet it seems probable that they might be manufactured so as to be economically used as fertilizers. The *silica* plants especially, would be greatly aided by such manures.

SULPHATE OF SODA, OR GLAUBER'S SALT.

$$SO_3 + NaO = 72.$$

Glauber's salt in its common form, like carbonate of soda, contains ten proportions of water, but loses it by efflorescence, and becomes a white powder. In the process given for obtaining muriatic acid from common salt, (page 51) the sulphate of soda is formed in the flask. This salt is always obtained in large quantities in the manufacture of muriatic acid.

What does soda form by combination with silica? Why are the silicates important? Where do they occur? What is the chemical constitution of Glauber's salt? What is said of the manufacture of muriatic acid?

In the manufacture of carbonate of soda from common salt, (see page 78) the sulphate is first formed, and after being mixed with pulverized chalk and charcoal, exposed to a red heat; the carbonate thus produced is dissolved out, and the solution crystalized.

The action of the sulphate of soda upon vegetation is like that of the sulphate of potash. But the soda salt can be applied much more economically than that of potash, as it is afforded at a much lower price. Both salts are found in the ashes of plants. These compounds have the most favorable effect upon those plants that contain most sulphuric acid. Instances are given by Johnston, in which their application as manures resulted in a marked increase of the crop.

NITRATE OF LIME.

$$NO_3+CaO=82.$$

Nitrate of lime is a very deliquescent salt, and may be formed by the action of dilute nitric acid upon chalk; the solution after being evaporated to a syrup crystalizes. All the nitrates are formed in considerable quantity in nature, and the manner in which they are produced has been pointed out; but it may not be improper to introduce in this connection, a more full explanation of the changes connected with their formation. It is made evident by experiment, that nitric acid can be formed by the chemical combination of the gases oxygen and nitrogen as they exist in the atmosphere. In confirmation of this, we find a portion of nitric acid, combined with ammonia, in the water that falls during thunder showers. The combination of elements is produced in these instances by atmospheric electricity, but

---

Upon what plants do the sulphates act most favorably? How may nitrate of lime be formed? How is nitric acid sometimes formed?

it would appear that nitric acid is often produced in ordinary weather, and when there is no exhibition of electrical phenomena. This result seems to be produced whenever those substances that contain nitrogen are undergoing decomposition. All animal, and most vegetable substances give off ammonia in process of decomposition: the nitrogen of the ammonia seems to unite with the oxygen of the air, forming nitric acid, and, this, combining with the various bases contained in the soil, forms the nitrate of lime, potash, soda, &c. This is the process continually going on in those places where the nitrates accumulate so extensively, and the reason why they occur so abundantly is, that in these localities there is a greater abundance of animal and vegetable matter in the soil, that is slowly suffering decomposition. Any accumulation of decaying organic matter, accompanied by a sufficient quantity of earth, to supply the necessary bases, is to a certain extent a nitre bed. Compost heaps are of this nature.

Nitrate of lime is most generally formed in those localities where nitric acid is produced, because lime is almost always present in the soil. This nitrate occurs also in the limestone caverns of the west and south west, and from it large quantities of nitre are formed. Nitrate of lime is converted into saltpetre by the mixture of wood ashes with the earth containing the former salt: the nitric acid combining with potash leaves the lime.

The process for forming nitric acid was omitted in treating of the primary compounds, because the substances from which it is derived had not been examined. The acid may be formed from either of the nitrates, but of late has been obtained mostly from the nitrate of soda.

How is it formed in ordinary weather? With what does it combine? Why do the nitrates occur so abundantly in certain localities? What nitrate is most generally formed? How is nitrate of lime converted into saltpetre? From what is nitric acid usually obtained?

To prepare the acid, one part of strong sulphuric acid is poured upon two of nitrate of soda contained in a glass retort, and the mixture is subjected to heat; the acid, distilling over, condenses in a receiver cooled by the external application of cold water. Nitric acid has never been obtained free from water, and the commercial acid contains it in considerable quantity.

The action of nitrate of soda as a fertilizer, is similar to that of the other nitrates, but it can not be economically obtained for agricultural purposes, except in localities where it is rapidly formed by natural causes. Compost heaps, however, may be formed in which the different nitrates will accumulate to some extent. The agriculturist should recollect that the action of the nitrates is not favorable upon all crops and under all circumstances: since they sometimes increase the *straw*, at the expense of the *seed*, (see page 76.) Johnston suggests that the presence of lime in the soil, tends to insure the success of the nitrate; if so, it is probable that the nitrate of *lime* is a more valuable fertilizer than that of *soda* or *potash*.

CARBONATE OF LIME.

$$CO_2 + CaO = 50.$$

Chalk, limestone, and marble, different forms of the carbonate of lime, occur in immense quantities in the mineral crust of the earth, and are familiar to all. Carbonate of lime is insoluble in pure water, but water, saturated with carbonic acid dissolves about $\frac{1}{1500}$ of its weight of this substance. The water of springs, wells, &c., generally contains this acid, and hence we find a

Give the process. What is said of the action of nitrate of soda as a fertilizer? What is said of compost heaps? What effect is sometimes produced by the nitrates? Mention the different forms of carbonate of lime. Is the carbonate soluble in pure water? In what is it soluble?

portion of lime dissolved in such water, but when exposed for a length of time to the air, the carbonic acid passes off and the carbonate of lime is deposited. In *petrifying springs*, as they are called, this process is continually going on. The water, as it percolates through the limestone strata, dissolves a portion of the carbonate, but when it gushes from the hill side, or trickles from the rock, its carbonic acid is dissipated, and the carbonate of lime is deposited in exceedingly minute particles. When these particles come in contact with decaying vegetable matter, they gradually take the place of the disappearing atoms, and eventually produce in limestone an exact copy of the plant; in like manner animal forms are petrified.

Lime is an essential constituent of vegetable forms, and constitutes a large percentage of the ashes of certain plants; these are called *lime* plants. It is from the carbonate, without doubt, that lime is principally supplied to the plant, for, notwithstanding lime is often applied to soils in its caustic state,—having been freed from its carbonic acid by heat—yet it is very soon changed to a carbonate again by combination with the carbonic acid of the atmosphere. It would seem, then, entirely unnecessary to expel the carbonic acid, as is done in the lime kiln, if the lime is to be applied merely as food for the plant. Indeed it is certain that, in most cases, the only benefit arising from burning lime that is to be used for agricultural purposes, is this: the rock is thus rendered easily reducible to a fine powder, but in this point of view it is not necessary to have recourse to burned lime, since the various marls that occur in such vast quantities, are in a sufficiently finely divided state, and can be applied with little trouble.

When spring water is exposed to the air what follows? Describe the process continually going on in petrifying springs. What are lime plants? What change takes place in caustic lime applied to the soil? What benefit arising from burning lime? What may be substituted for it?

The carbonate in this form may be in ordinary cases, as profitably used as the more expensive burned lime. Caustic lime, as is stated elsewhere, is required whenever animal or vegetable substances are to be decomposed rapidly, and slacked lime may be applied when the same decomposition is to be gradually effected, but when lime is to be supplied merely as food for the plant, there is no advantage in applying it in the form of quicklime. Marl may be obtained by most farmers with little difficulty, and is the cheapest form in which the carbonate can be applied. But the action of the carbonate is not confined to supplying lime directly to the plant; it possesses the same power of decomposing vegetable matter that is possessed by caustic lime, though not to that degree. Certain acids are produced during the decomposition of vegetable matter that have the effect of arresting the further decay of those substances, and in addition to this, are prejudicial to the growing plant. These acids decompose the carbonate, uniting with its lime, and gradually releasing the carbonic acid. Thus the unfavorable action of the vegetable acids is prevented, and carbonic acid is supplied to the plant.

The various modes in which the carbonate acts, will be more fully treated of hereafter.

SILICATE OF LIME.

The silicate of lime occurs as a constituent of certain minerals, and since soils arise from the disintegration of the various mineral masses, it follows that this silicate is, to some extent at least, a constituent of the soils. It occurs in the ashes of plants.

When is caustic lime required? What is said of the action of a carbonate? What effect does it have upon certain acids? Is silicate of lime a constituent of soils?

On account of the insolubility of this silicate, it does not directly supply nourishment to the plant, but like the other silicates, is slowly decomposed by the carbonic acid of the atmosphere, thus, eventually supplying both carbonate of lime and silica to the plant. It will be recollected that when silica is first released from its combination with the various bases, it is to some extent soluble in pure water, and the solutions of potash, soda, &c., readily combine with it in this state, forming soluble silicates in the soil. The action of silicate of lime upon vegetation, depends upon this process of decomposition, but it is not decomposed by carbonic acid only; the acids which are formed during the decay of vegetable substances, by combination with the lime of this silicate, release the silica; by this union the acids, before hostile to vegetable life, are rendered harmless.

Lime and sand mixed as in the preparation of mortar unite chemically, producing the silicate of lime, and the same effect is produced to a certain extent, when lime is applied to siliceous soils. This compound is not only useless as long as it remains undecomposed, but is really injurious when remaining unchanged in considerable quantity in the soil. If then lime be applied to sandy land those substances should accompany it which will ensure its decomposition, for the carbonic acid of the air alone will not produce the requisite change. Vegetable matter supplies carbonic acid and other decomposing substances to the insoluble silicates, and thus provides ample means for accomplishing the required decomposition. Lime, then, should always be

---

Is it a soluble salt? By what is it slowly decomposed? With what does the carbonic acid unite? What compound is formed? What is said of silica when first released from its combinations? What is said of other decomposing agents besides carbonic acid? What compound is formed in the preparation of mortar? When is the same compound formed in the soil? What direction are given with reference to the application of lime to siliceous soils?

accompanied by vegetable matter in some form when applied to light soils, unless there is already an accumulation of such matter in the soil.

It has been observed that the soils formed by the disintegration of those rocks which contain the silicate of lime, are exceedingly fertile, but most soils are derived from rocks that contain very little of this compound. Those varieties of lime stone which contain a portion of sand, would probably prove most valuable as a fertilizer; in such the silex and lime sometimes combine during the process of burning, and the silicate of lime is formed.

SULPHATE OF LIME, GYPSUM, OR PLASTER.

$$SO_3 + CaO = 68.$$

By the action of sulphuric acid upon lime or any soluble salt of lime, the sulphate of this base is produced. It is not necessary, however, to prepare it artificially, as it occurs in various forms and in immense quantities. The common *plaster* is an impure form, containing an admixture of earthy matter; it occurs as the part of the rock formations of the New York system, not in beds or layers, but in detached and irregular masses. There is a purer, crystalized variety of this salt called *gypsum*, which, exposed to heat, loses the two proportions of water usually contained by it, and is changed to a dry white powder called *plaster of Paris*. In this state, it is fitted for giving a *hard finish* to walls or for producing plaster casts, &c. In these operations the plaster *sets*, as it is termed, by virtue of its avidity for moisture; the water which has been driven off by heat is rapidly

---

What is the nature of soils containing the silicate of lime? Give the chemical constitution of the sulphate of lime. Mention the different varieties found in nature. What effect is produced upon gypsum by exposure to heat? What causes plaster of Paris to *set?*

taken up when mixed with the plaster, and the expansion of the mixture produces an exact copy of the mould. Alabaster is another form of the sulphate quite pure and translucent.

This salt of lime is slightly soluble in water ; a gallon of this fluid dissolving about one quarter of an ounce of the sulphate.

Sulphate of lime is one of the most valuable fertilizers, and can generally be obtained at a price that will admit of its being economically applied to the soil. It is found in the ashes of plants, and is a constituent of most soils, although generally occurring in minute quantities. Its presence is absolutely requisite to the perfection of the plant, and since it is sparingly disseminated in the soil it is not strange that the application of it to the growing crop has produced favorable results. Those crops are most benefited which contain most of the sulphate in their ashes. Yet it must not be inferred that the only office of this compound is, to supply food to the plant from its own substance. Its action in decomposing the carbonate of ammonia and giving to the volatile gas a *fixed* form, is probably more important than the mere act of supplying sulphate of lime to the plant. The following experiment given by Petzholdt illustrates the changes produced by gypsum upon carbonate of ammonia.

" A small plot of garden ground was manured with fresh horse-dung, and then sowed with peas and beans —the surface was then covered with a thin layer of uncalcined gypsum. The ground was protected from rain, and watered in dry weather. All the beans and peas grew up with extraordinary rapidity and luxuriance. Before commencing the experiment, the soil, as

---

What is said of the solubility of this sulphate? Of its importance as a fertilizer? What crops are most benefited? Give the effect of this sulphate upon carbonate of ammonia?

well as the gypsum, was accurately tested, and exhibited not the slightest trace of a carbonate. But when after the lapse of three weeks, the gypsum was removed from the surface and tested, the greater part of it was found to have become transformed into carbonate of lime; the whole soil to the depth of six inches effervesced strongly with acids. The soil was lixivated with cold water, the fluid filtered, and after evaporation a considerable amount of sulphate of ammonia remained. The very slight solubility of gypsum in water, and the slowness of its decomposition by carbonate of ammonia, explain the favorable action of gypsum as a manure, and the reason why its effects are not transitory but remain for years."

It seems then, that when sulphate of lime and carbonate of ammonia are in contact, double decomposition ensues; the sulphuric acid of the former uniting with the ammonia of the latter, forms sulphate of ammonia; the carbonic acid and remaining base, form carbonate of lime. In this process, ammonia is changed from a volatile to a fixed form, and is thus retained for the nourishment of the plant.

Since this sulphate requires a considerable portion of water to dissolve it, its action upon dry soils will not be as apparent as upon those supplied with the requisite degree of moisture. The sulphates of potash and soda produce the same effect upon vegetation as that of lime, as far as a supply of sulphuric acid is concerned, and it is probable that they even form the sulphate of lime in the soil, whenever lime is present to decompose these salts, but gypsum can be obtained at much less expense

---

To what was the sulphate of lime changed in the experiment given? What was obtained from the soil? What decomposition is produced when carbonate of ammonia and sulphate of lime are in contact? How is ammonia effected in this change? What is said of the action of sulphate of lime upon dry soil? What is said of the sulphate of potash and soda?

than the other sulphates, and hence, is preferable as a fertilizer; there may be cases, however, in which the application of the more soluble sulphates will be advisable, as upon very dry soils where there is not sufficient moisture to dissolve the sulphate of lime.

If the action of plaster is such as is indicated by the experiment given, the importance of its application to all places where ammonia is produced, is evident. If it be strewed upon the floors of stables, mixed with manures, or spread over the surface of compost heaps, it will effectually secure that element which otherwise will pass quickly away, and be disseminated in the atmosphere.

PHOSPHATE OF LIME.

This compound of phosphoric acid and lime occurs in bones, constituting about 50 per cent. of their weight. The mineral called *apatite* is nearly pure phosphate of lime.

Phosphorus is an element of plants, and the only source from which it can be obtained is phosphoric acid, in its combinations with ammonia, lime, &c. It has been stated before, that the fertilizing power of guano, urine, &c., depends upon the presence of the phosphates. Bone dust probably owes its value as a fertilizer in most instances, to the presence of the phosphate of lime; upon this point, however, there seems to be something of a difference of opinion, as the following remarks of Johnston will indicate.

"When bones are buried in a more or less entire state, as they occasionally are about the roots of vines and fruit trees, they gradually decay, and sensibly promote the growth of the trees to which they are applied.

In what cases will they act more favorably than sulphate of lime? Where should plaster be applied? Where does the phosphate of lime occur? To what is the fertilizing power of guano, &c. owing?

Yet after the lapse of years these same bones may be dug up nearly unaltered either in form or in size. The bones of a bear, after being long buried, were found by Marchand to consist of

BONES OF THE BEAR BURIED.

	Deep.	Shallow.
Animal matter,	16·2	4·2
Phosphate of lime,	56·0	62·1
Carbonate of lime,	13·1	13·3
Sulphate of lime,	7·1	12·3
Phosphate of magnesia,	0·3	0·5
Fluoride of calcium,	2·0	2·1
Oxide of iron and manganese,	2·0	2·1
Soda,	1·1	1·3
Silica,	2·2	2·1
	100	100

The most striking change undergone by these bones was the large loss of organic or animal matter they had suffered. The relative proportions of the phosphate and carbonate of lime had been comparatively little altered. The *main* effect, therefore, produced by bones when buried at the roots of trees, and their *first* effect in all cases, must be owing to the animal matter they contain—the elements of this animal matter, as it decomposes, being absorbed by the roots with which the bones are in contact.

Such facts as this prove, I think, the incorrectness of the one-sided opinion too hastily advanced by Sprengel, and after him reiterated by Liebig and his followers—that the principal efficacy of bones is, in all cases, to be ascribed to their earthy ingredients, and especially to the phosphate of lime."

What difference of opinion has arisen with regard to bone dust? In the experiment given what loss did the bones suffer?

Probably this difference of opinion arises from considering the bones in different states; they contain besides phosphate of lime, nearly 50 per cent. of animal matter, rich in nitrogen. If the bones be crushed while they yet retain this matter, their influence upon vegetation will be favorable, on account of the supply of ammonia yielded by the decomposition of the more destructible part of the bone, and the effect produced will be more immediately perceived than if the pure phosphate is applied. By boiling, a portion of animal matter is separated from the bones, and they are rendered less valuable: yet this process seems to fit them for more rapid decomposition, and therefore their effect when applied to the soil is often quite as marked as that of the unboiled.

When bones are burned that they may be the more easily pulverized, all the gelatinous matter is driven off and the remaining mineral mass is mostly phosphate of lime. The bone dust thus obtained, when applied to soil destitute of the phosphates, produces exceedingly favorable results. If there is already a supply of phosphate of lime in the soil, this form of bone earth will produce no effect, but those forms which contain a portion of animal matter, will promote vegetation even when no phosphate is required, and in such cases the result will be seen to indicate that the phosphate of the bones is of comparatively little importance.

Whenever the compounds of phosphoric acid are wanting in the soil, the application of bone dust, in any state, will greatly promote the growth of the plant by supplying phosphoric acid.

The difference of opinion which we have noticed, has arisen from the difference of circumstances under which

---

What inference is drawn from this experiment? State the different modes of preparing bones? What is said of bone dust that contains no animal matter?

experiments have been conducted; Liebig, however, does not suppose the gelatine of bones of no effect upon vegetation, as is evident from the following remarks.

"One hundred parts of dry bones contain from 32 to 33 per cent. of dry gelatine; now, supposing this to contain the same quantity of nitrogen as animal glue, viz. 5·28 per cent., then one hundred parts of bones must be considered as equivalent to two hundred and fifty parts of human urine.

Bones may be preserved unchanged for thousands of years, in dry or even in moist soils, provided the access of rain is prevented, as is exemplified by the bones of antedeluvian animals found in loam or gypsum, the interior parts being protected by the exterior from the action of water. But they become warm when reduced to a fine powder, and moistened bones generate heat and enter into putrefaction; the gelatine which they contain is decomposed, and its nitrogen converted into carbonate of ammonia and other ammoniacal salts, which are retained in a great measure by the powder itself. (Bones burnt till quite white, and recently heated to redness, absorb 7·5 times their volume of pure ammoniacal gas."

Both authors from whom we have quoted upon this point, are convinced of the two-fold action of crushed bones, but one considers the organic part of them more efficacious, the other thinks the mineral portion more beneficial to vegetation. It seems probable, that whenever a supply of the phosphate is demanded, the soil being destitute of it, bone dust is principally useful on account of its mineral constituents.

Some marls contain a portion of the phosphate of lime, and to the presence of this their favorable influence upon vegetation may, in part, be attributed.

What is Liebig's view with respect to the effect of the gelatine of bones? Burnt bones absorb what? What is said of some marls?

NITRATE OF MAGNESIA.

$$NO_5 + MgO = 74.$$

This salt may be prepared by dissolving carbonate of magnesia in nitric acid, and evaporating the solution. It is formed in nature in the same way that the other nitrates are produced. Its action upon vegetation is like that of the nitrates of lime as far as a supply of nitrogen to the plant is concerned; certain of the more soluble salts of magnesia, however, have been supposed to act unfavorably, when occurring in the soil in too great quantities.

The nitrates of magnesia can be easily decomposed by potash, as is the nitrate of lime in the manufacture of nitre.

A supply of magnesia is requisite to the perfect development of the plant. Yet care must be taken that a limited quantity be applied; it is not generally applied in the form of the nitrate, except as this salt may occur in the compost heap. The following is the most common salt of magnesia.

CARBONATE OF MAGNESIA.

$$CO_2 + MgO = 42.$$

It has been before stated that magnesia occurs in certain mineral masses called magnesian limestones; in these it is found in the form of a carbonate. When those varieties of limestone which contain magnesia are applied to the soil, the result is sometimes unfavorable on account of the union of certain acids, with the

---

How is nitrate of magnesia formed in nature? What is said of its action upon vegetation? How may the nitrate of magnesia be decomposed?

base forming soluble compounds unfavorable to vegetation.

When magnesian limestone is burned, the magnesia is rendered caustic, as well as the lime, and by its mixture with the silica of the soil, has a tendency to form a hard mortar, thus rendering the soil stiff and in a measure impenetrable, preventing the extension of the roots of the plant. Carbonic acid does not unite as readily with magnesia as it does with lime, and therefore the former substance remains in a caustic state longer than the latter; the unfavorable action of magnesia in large quantities may be, in part, owing to this. The magnesia of commerce is generally in the caustic form, but if exposed to the air will be changed gradually to the carbonate.

SILICATE OF MAGNESIA.

The silicate of magnesia occurs in certain mineral forms, of which the most common are *soapstone* and *serpentine;* soils therefore contain this compound, at least in some localities. On account of the insolubility of this silicate, it can not under ordinary circumstances prove hurtful to vegetation, but on the contrary, as it is slowly decomposed by carbonic acid, will provide both silica and magnesia to the growing plant.

SULPHATE OF MAGNESIA, OR EPSOM SALTS.

$$SO_3 + MgO = 60.$$

This salt is manufactured in large quantities from sea water, in connection with the manufacture of common salt; the latter substance is first separated by

---

What is the effect of burning magnesian limestone? When this mixture is applied to the soil what is the result? Why does magnesia act unfavorably on vegetation? In what mineral does the silicate of magnesia occur? What will this compound supply to the plant?

evaporating the water until only a small portion remains and removing the crystalized salt; the remaining fluid is called *mother liquor*, or *bittern*, and contains sulphate and carbonate of magnesia; by supplying sulphuric acid, the latter is decomposed and the sulphate formed; from this solution the salt is obtained by evaporation.

Sulphate of magnesia is also obtained by dissolving magnesian limestone in dilute sulphuric acid; the insoluble sulphate of lime formed at the same time, is easily removed and from the remaining liquid the salt is obtained by evaporation. The common name *Epsom salts* is derived from the place Epsom, where the mineral waters contain this salt.

The application of this substance as a fertilizer, in the few cases of which we have any knowledge, has resulted favorably; its action being similar to that of the other sulphates, but it can not be economically applied at present.

Phosphate of magnesia.—This compound of phosphoric acid and magnesia, although not of common occurrence, is obtained in the analysis of plants, being contained especially in the grains of wheat, rye, &c., and is an important constituent. Bone earth contains a portion of this phosphate, and it also occurs in minute quantity in certain manures. It is supposed, however, that the phosphoric acid and magnesia are generally obtained by the plant from different sources, and are combined within the plant, forming this compound.

What is the chemical constitution of Epsom salts? By what process is it obtained from sea-water? From what other source is it obtained? Has it produced favorable results when applied to the soil? Where does phosphate of magnesia occur?

SULPHATE OF IRON, OR COPPERAS.

$$SO_3 + FeO = 76.$$

This well known salt may be formed by dissolving iron in dilute sulphuric acid, and evaporating the solution. In its ordinary crystaline state it contains seven atoms of water which it yields up when exposed to heat. Copperas is frequently formed in soils that contain a certain compound of sulphur and iron, called *bisulphuret of Iron;* by the presence of air and moisture the sulphur of this compound is converted into sulphuric acid which, uniting with the iron, forms the sulphate of that metal. The presence of this salt in considerable quantity, is unfavorable to vegetation, but it may be easily decomposed by quicklime.

CARBONATE OF IRON.

$$CO_2 + FeO = 58.$$

The sulphate of iron just described, may be decomposed by carbonate of soda; the carbonic acid of the latter compound uniting with the iron, forms carbonate of iron. Whenever the sulphate occurs in the soil, it is slowly decomposed by the carbonates. Carbonate of iron is slightly soluble in water containing carbonic acid, and when dissolved by it, enters into the plant; probably most of the iron essential to the plant, is obtained in this way.

What is the chemical name of copperas? How may it be obtained? How is it formed in soils? What is its effect when occurring in excess? How may this salt be decomposed? When decomposed by carbonate of soda what is formed? In what form does iron enter the plant?

SALTS OF MANGANESE.

Manganese is an essential constituent of plants, although it is found in very minute quantities in their ashes, and since the oxides of this metal are insoluble in water, a supply must be obtained from some other compounds.

The *sulphate of manganese* is sometimes formed in the soil; and its presence in limited quantity, is without doubt favorable to vegetation.

The *carbonate of manganese*, is formed from the sulphate, and is soluble in certain acids usually existing in the soil; these soluble compounds supply manganese to the plant.

SILICATE OF ALUMINA.

Alumina as it exists in the soil generally has a portion of silica combined with it, forming the silicate of alumina, this is the composition of the various clays, and the majority of all minerals contain this silicate. The different varieties of porcelain, china, and earthen ware are silicates of alumina, more or less pure.

The presence of this compound in the soil is necessary, to render it sufficiently retentive of moisture; but from its insolubility probably does not directly supply food to the plant. Allusion has been made to the fact, that alumina possesses the property of absorbing ammonia, and doubtless it is an important office of clay, to supply ammonia to the plant. If, however, the clay is too compact, it seems to retain the ammonia with too much force. The application of lime, will to a certain extent, remedy this.

Are the oxides of manganese soluble? Does sulphate of manganese occur in soils? What is said of carbonate of manganese? In what form does silica exist in the soil? What is said of porcelain ware, &c.? What important office does clay perform? What must be applied when clay is too compact?

General action of the silicates.—The great importance of silica in the production of vegetable forms, renders a few general explanations necessary with respect to the manner in which the silicates promote vegetation. It has been stated that pure silica, in its ordinary state, is insoluble in water, yet it is a peculiarity of this substance, to which allusion has been made, that it is under certain circumstances, slightly soluble. If the soluble glass described on page 73 be decomposed by applying an acid, the silica will be deposited in a soft gelatinous state; this form of silica, before it it is dried, is soluble in water, or in solutions of the alkalies, potash, soda, &c., but after it has been thoroughly dried it becomes insoluble again. The insoluble silicates of lime, magnesia, potash, soda, &c., are slowly decomposed by carbonic acid and other agencies, and the silica is separated in this gelatinous, soluble state; in this form it can be taken up by the plant dissolved in water, or if the alkalies, potash, soda, &c., exist in a free state in the soil, they combine with the silica, forming soluble compounds that are absorbed by vegetable forms.

RECAPITULATION.

For the purpose of fixing in the mind of the learner, the connection and general bearing of the preceding pages, a brief recapitulation is here given, of the nature of those substances that make up the plant, and the sources from which they are derived.

Elementary substances contained by plants.

Oxygen, hydrogen, nitrogen, carbon, silicon, sulphur, phosphorus, chlorine, iodine, bromine, fluorine, potassi-

---

What is said of silica in its ordinary state? When soluble glass is decomposed in what form is silica deposited? What peculiar property of silica when in this state?

um, sodium, calcium, magnesium, iron, manganese and aluminum.

These elements are sometimes divided into two classes, *organic* and *inorganic;* those which disappear when the plant is burnt in the open air, viz., oxygen, hydrogen, nitrogen, and carbon, are called *organic elements*; those which remain in the ashes are called *inorganic.*

The organic elements constitute from 88 to 99 per cent. of the plant.

Properties of the different elements and sources from which they are derived.

Oxygen.—This element is a transparent, tasteless, and inodorous gas, a little heavier than atmospheric air. It is the great supporter of combustion and respiration, and is essential to both animal and vegetable life.

This gas constitutes from 35 to 45 per cent. of the various vegetable substances cultivated for food.

The source from which oxygen is principally obtained is water, which, it will be recollected is a compound of oxygen and hydrogen. It may not however be wholly derived from the constituents of water, for this liquid generally contains a small quantity of the oxygen of the air dissolved in it, which is conveyed with it into the plant, and it is quite possible that a portion of the oxygen of vegetable substances is thus derived from the atmosphere.

Hydrogen.—This element also is colorless, tasteless, and inodorous when pure, and 14 times lighter than air. It will support neither combustion nor respiration, but is itself inflammable.

Hydrogen constitutes from 5 to 7 per cent. of the elements of vegetable forms. It will be noticed that oxygen and hydrogen exist in the plant in nearly the proportions to form water, but that hydrogen is somewhat in excess.

Water is doubtless the principal source from which this element also is obtained, but it is quite probable that it is also supplied by the decomposition of ammonia, the constitution of which is NH_3.

Nitrogen.—This gas is similar to oxygen and hydrogen in its appearance, and is a little lighter than common air. It will not support combustion, and although not poisonous in its nature, is not a supporter of animal life; we can not live in an atmosphere of pure nitrogen for the same reason that we can not exist for any length of time beneath the surface of water—because there is not a supply of oxygen.

The amount of nitrogen in different plants cultivated for food varies from 1 to 7 per cent., and sometimes occurs in the plant as a constituent of saltpetre which is sometimes found in the stem.

This element is principally obtained from ammonia, but may be in part obtained from the air, since all of the constituents of the atmosphere are dissolved in the water taken into the circulation of the plant.

Nitrogen is sometimes obtained from the different nitrates occurring in the soil, the most common of which is saltpetre. In some localities nitrates accumulate in immense quantities: and in such places these salts have proved hostile to vegetable life; but in most situations a very limited quantity is formed, and in many soils not a trace of any of the nitrates can be found. We must depend then upon ammonia as the principal source from which nitrogen is to be supplied to vegetation.

In the decay of animal and vegetable forms this gas is evolved; such substances, therefore, should be supplied to the soil, at the same time those *fixers* of ammonia of which we have before spoken should be applied for the purpose of retaining this important element.

Carbon.—The diamond, charcoal, and black lead, are different forms of carbon; the first pure, the others nearly so.

Carbon constitutes from 40 to 50 per cent. of vegetable forms.

Most soils contain a portion of vegetable matter, which consists principally of carbon; this is gradually changed to carbonic acid which is dissolved in water, and thus easily conveyed into the vegetable structure; but it is from the atmosphere and not from decaying vegetable matter, that plants obtain most of their carbon. During the day the leaves absorb carbonic acid from the air, retaining the carbon and returning the oxygen.

Silicon.—This element is found in plants in combination with oxygen, forming silica. It is this that gives strength to the slender stalk, and enables it to bear up the heavy grain.

The sources from which silica is derived have been pointed out at length; it is ever derived from the silicates of lime, potash, soda, &c.

Sulphur.—This familiar substance is not obtained from the plant in its simple form, but is found combined with oxygen, forming sulphuric acid, and this acid is generally found combined with lime. Sulphate of lime is the principal source from which the plant obtains this constituent, though other sulphates sometimes occur in the soil.

Phosphorus.—The element phosphorus can not be assimilated in its elementary form, and does not occur in this form in the ashes of plants: phosphoric acid combined with lime and magnesia are obtained in the analysis of plants, and without doubt it is taken up by the plant, to some extent, in the form of the different phosphates.

Chlorine.—The element chlorine is a greenish yellow gas, and in its pure state, destructive of animal and vegetable life. It is not assimilated by the plant in its elementary state. Combined with the metal sodium, forming common salt, (chloride of sodium,) it is detected in soils, and from this compound most of the chlorine of the plant is derived. Other compounds, such as the chloride of calcium, sometimes occur in the soil, from which chlorine may be derived.

Potassium.—It will be remembered that potassium is a soft metal that takes fire when thrown upon water, absorbing the oxygen of that liquid and being converted into potash. This element does not occur in its metallic form, and is not obtained from plants in this state, but is found in their ashes in the form of potash or salts of potash. The vegetable matter of the soil yields a portion of potash to the plant, in the process of decomposition, and most soils contain more or less of the salts of this base. Whenever soils are deficient in this compound it may be economically supplied in the form of wood ashes.

Sodium.—This element is a metal, white like silver, and in most of its properties similar to potassium. It does not occur in its metallic state, either in soils or in the ashes of plants.

Sodium occurs very extensively in nature combined with chlorine, forming common salt, and from this compound, vegetable forms, in part, obtain the element under consideration. Soda, a compound formed by the union of oxygen with the metal, is also contained in soils, and from it this element is readily obtained.

Calcium.—A white metal derived from lime is called calcium. The ashes of plants never contain this element uncombined with others, and it does not occur in its metallic state.

Calcium may be obtained for the purpose of vegetable organization from a number of different compounds —common burned lime, chalk, marl, plaster, &c. Most soils are supplied with lime to some extent, and when there is a deficiency, materials are at hand and can easily be obtained by the agriculturist for remedying the defect.

Of the remaining elements it is hardly necessary to speak again, as they usually occur in the soil in sufficient quantity to supply the wants of vegetation.

ORGANIC COMPOUNDS.

From vegetable forms, a class of compounds may be obtained, quite unlike those which have been described. Starch, sugar, vinegar, &c., are produced by different processes from vegetable substances, and are of very constant chemical composition. Of these the first two are composed of 12 atoms of carbon, 10 of hydrogen, and 10 of oxygen, and the compounds are expressed by the formula $C_{12} H_{10} O_{10}$. The constitution of vinegar, or acetic acid is indicated by the formula $C_4 H_3 O_3$. They are constituted of definite proportions of the different elements, and have received the name of *organic compounds*. There is a great number of these, some derived from vegetable and some from animal substances. They seem to be originated by the vital forces that produce the organization of animal and vegetable forms, and very few of them can be produced by the chemist by the union of the elements of which they are composed; some of the compounds heretofore described are by some, ranked among organic compounds.

It is exceedingly difficult to point out distinctly, the difference between organic and inorganic forms, but a

---

Mention some organic compounds? What is their constitution?

few characteristics of the former will be given, which will form something of a line of division between the two classes.

1. Organic compounds are remarkable for the complexity of their *atomic* constitution. The elements of which they are composed are quite limited in number; most vegetable organic bodies being made up of carbon, oxygen, and hydrogen, those of animal origin contain nitrogen also; but the number of atoms combined in these bodies is very great.

2. By the application of heat these substances are charred and eventually decomposed.

3. They are exceedingly prone to decomposition even by ordinary exposure to air and moisture.

A description of the properties of a few of these substances is here given, since they will be mentioned occasionally in the succeeding pages. Some of them are supposed to exert a favorable influence upon vegetation, whilst others are apparently injurious.

HUMUS.

A brown substance consisting of carbon, oxygen, and hydrogen, is produced by the decay of vegetable substances in the soil and is called humus. In the process of decay vegetable matter is continually changing its chemical composition; oxygen is slowly absorbed from the air and the changes that ensue produce carbonic acid and water, the former being formed by the union of the carbon and oxygen of the plant, the latter by the combination of the oxygen of the air with the hydrogen of the decomposing substance.

The result of this gradual change is, that a large

What are the characteristics of organic compounds? What is the composition of humus? What changes occur in the decay of vegetable matter? What compounds are formed?

number of compounds are formed, possessing the same elements and somewhat similar properties, but differing in the proportion in which those elements occur. *Geine, ulmin, humic acid, humin*, &c., are different names applied to the varieties thus produced, but they may all be considered as modifications of *humus*. The difference of composition is probably in some cases owing to the kind of vegetable from which the substance is obtained.

The term *vegetable mould* as used by farmers, may apply to the different forms of humus as they occur in the soil mixed with inorganic matters. A part of the humus is soluble in alkalies, and may be obtained from most soils by the following process. First wash the soil and then boil it in a solution of the carbonate of soda or potash in water : a colored fluid will be obtained from which soluble humus, or humic acid, may be obtained by adding muriatic acid. It will be precipitated in the form of a dark flocculent substance, very slightly soluble in water. This process does not dissolve the whole of the vegetable mould, and the remaining mass contains a variety of humus sometimes called *insoluble geine*. Different terms, however, are used by different authors. "The modifications of *humus* which are soluble in alkalies, are called *humic acid;* while those which are insoluble have received the designations of *humin* and *coal of humus*." (Liebig.)

Soluble humus forms compounds with the potash, soda, lime, &c. of the soil, and may be taken up by the roots of the plant, but with respect to the influence which these combinations exert upon vegetation, there is a wide difference of opinion. Some maintain that humus or its compounds taken up by the roots yields its carbon to the plant, and thus becomes an all important

---

By what different names are they called? What is said of the term *vegetable mould?* How is soluble humus obtained? Describe it. To what compound is the term humic acid applied and to what humin?

source of nourishment. Others deny that any favorable effect is produced by the humus contained in the soil. Liebig shows pretty conclusively that plants can not obtain their carbon from humic acid or its compounds. The following are his reasons in a condensed form.

"The opinion that the substance called *humus* is extracted from the soil by the roots of plants, and that the carbon entering into its composition serves in some form or other to nourish their tissues, is so general and so firmly established, that hitherto any new argument in favor has been considered unnecessary; the obvious difference in the growth of plants according to the known abundance or scarcity of *humus* in the soil, seemed to afford incontestable proof of its correctness. Yet, this position, when submitted to a strict examination, is found to be untenable, and it becomes evident from most conclusive proofs that humus in the form in which it exists in the soil, does not yield the smallest nourishment to plants.

Vegetable physiologists agree in the supposition that by the aid of water, *humus* is rendered capable of being absorbed by the roots of plants. But according to the observation of chemists, humic acid is soluble only when newly precipitated, and becomes completely insoluble when dried in the air, or when exposed in the moist state to the freezing temperature.

Both the cold of winter and the heat of summer therefore are destructive of the solubility of humic acid, and at the same time of its capability of being assimilated by plants, so that, if it is absorbed by plants, it must be in some altered form. Facts, which show that humic acid in its unaltered condition can not serve for the nourishment of plants, have not escaped the notice of physiologists; and hence they have assumed that the

---

What difference of opinion is mentioned? Give Liebig's view. What does he say of the solubility of humic acid?

lime or the different alkalies found in the ashes of vegetables, render soluble the humic acid and fit it for the process of assimilation.

Alkalies and alkaline earths do exist in the different kinds of soil, in sufficient quantity to form such soluble compounds with the humic acid.

Now, let us suppose that humic acid is absorbed by plants in the form of that salt which contains the largest proportion of humic acid, namely in the form of humate of lime, and then from the known quantity of the alkaline bases contained in the ashes of plants, let us calculate the amount of humic acid which might be assimilated in this manner. Let us admit likewise, that potash, soda, and the oxides of iron and manganese have the same capacity of saturation, as lime with respect to humic acid.

40,000 square feet of woodland yield annually, according to Dr. Heyer, on an average, 2,650 lbs. of dry fir wood, which contain 56 lbs. of metallic oxides.

Now, according to the estimates of Malaguti and Sprengel, 1 lb. of lime combines chemically with 10·9 lbs. of humic acid, which, admitting humic acid to contain 58 per cent. of carbon, would correspond to 91 lbs. of dry-wood. But we have seen that 2,650 lbs. of fir wood are really produced."

The inference from this estimate is, that if all the potash, soda, lime, magnesia, iron, and manganese, contained in the fir-tree is taken up in combination with humic acid, the amount of carbon supplied in this way would be very small compared with the amount really existing in the tree,—only about $\frac{1}{29}$ of the whole.

By another estimate, the same author shows that if all the rain water which falls during the summer months, should enter the plant, having in solution as

---

According to his estimate what portion of the carbon of the plant may possibly be supplied by humic acid?

much as can be dissolved by it of the humate of lime (the most soluble of the humates;) but a small portion of humic acid would be received, and a very insufficient quantity of carbon assimulated.

It must not be inferred however that Leibig supposes humus unimportant or of little consequence as a fertilizer. His argument is given to show that the absorption of *humic acid* by the plant, either combined or uncombined would not supply the requisite amount of carbon to the plant, but it is admitted that humus is a source from which this important element is derived. The following is his language on this point.

"Humus acts in the same manner in a soil permeable to air as in the air itself; it is a continued source of carbonic acid, which it emits very slowly. An atmosphere of carbonic acid, formed at the expense of the oxygen of the air surrounds every particle of decaying humus. The cultivation of land, by tilling and loosening the soil, causes a free and unobstructed access of air. An atmosphere of carbonic acid is, therefore contained in every fertile soil, and is the first and most important food for the young plants which grow in it."

Although it is evident that soils are most productive which contain a proportion of vegetable mould, yet it is no less certain that vegetable forms whether plants cultivated for food, or forest trees, derive their carbon mostly from the *air*. It is certain too that large crops are often obtained from soils containing very little humus or carbonaceous matter in any form.

What then, is the function of *humus* in the great process of vegetable organization? Is its presence necessary in order to provide carbon for the plant.?

What other estimate by the same author? Does Leibig suppose humus of no avail? What does his argument show? How does he say that humus acts? From what source do plants mostly derive their carbon?

It is not absolutely required for the purpose of supplying carbon, after the plant has appeared above the ground and opened its leaves to the air, for it is principally through the leaves that the carbonic acid of the air is taken up; but before the tender shoot is supplied with exterior organs, and while its roots are the only absorbents of carbonic acid, humus in process of decomposition doubtless supplies nourishment.

OXALIC ACID.

$C_2\ O_3=36.$

This acid is found in certain plants, generally in combination with potash or lime. It is a transparent crystaline substance, sour to the taste, and poisonous. It is not only destructive of animal life, but is prejudicial to most vegetable forms which are cultivated for food.

Oxalic acid may be formed artificially by the action of nitric acid upon starch. It unites freely with lime, potash, soda and other bases; the oxalate of lime is totally insoluble in water, and therefore, when oxalic acid occurs in the soil, it can be rendered harmless by the application of lime. The presence of sorrel upon a piece of ground indicates the existence of this acid in quantities hurtful to vegetation, and lime should be immediately applied to neutralize it.

From sorrel is obtained the oxalate of potash which from its origin is called *salt of sorrel.*

Under what circumstances does humic acid supply nourishment to the plant? What is the composition of oxalic acid? Describe it. How may it be formed artificially? What does the presence of sorrel on a soil indicate? How may the oxalic acid be neutralized? What salt is obtained from sorrel?

ACETIC ACID, OR VINEGAR.

Common vinegar is a very dilute and impure form of acetic acid, but can be freed from its impurities by distillation. This acid occurs in the juices of many plants, and may be obtained from common wood by exposing this to a high heat in an iron retort; the acid distils over and by means of a condensing apparatus is collected, but in an impure state; certain oily and tarry substances are produced by the same process, and must be separated from the acetous liquor.

A large number of organic compounds are formed in the plant, and may be separated from them by different processes, but it will not be profitable to go into an examination of them here; we hence close the consideration of those substances which constitute the plant and examine the *forces* or *agents* which produce the requisite combinations in the organization of vegetable forms.

What is common vinegar? How is acetic acid obtained from wood?

PART IV.

CHEMICAL FORCES.

We have seen that there is in nature a limited number of elementary forms, and that these elements unite with each other, producing an almost infinite variety of compounds.

Now as no effect is without a cause, and no change produced except by some active force, it follows that certain agencies must be in action that cause the union of elements or compounds with each other, or separate them when united. The chemical forces are attraction, heat, light, and electricity. The phenomena connected with the manifestations of these different forces, are in some points similar, and it is possible that after investigation may prove the identity of different forces, indeed they may all prove to be modifications of one universal, all-pervading agent.

ATTRACTION.

This agent will be examined under four different modifications, gravitation, cohesion, capillary attraction, and chemical affinity. The first three do not have a direct bearing upon this department of science, but are incidentally connected with it.

Gravitative attraction is an all prevading property of matter, we see its effect not only in the fall of the acorn from the oak, or the destructive descent of the avalanche from its dizzy height, but in the descent of

---

What forces produce chemical changes? Give three kinds of attraction mentioned.

the smoke towards the earth, and the lowering of the clouds when their density is increased. The effect of gravity is not only to make things *gravitate* towards the earth, but in an equal degree proportionally, to make them gravitate towards each other.

Two balls suspended by cords at a short distance from each other, have not only a tendency towards the earth, but towards their own centres.

All have observed that different bodies move towards the earth with different forces, and if we were asked why this was so, we might perhaps answer "because some bodies weigh more than others," forgetting that what we term *weight* is only the gravitating force of the substance which we weigh. This force depends upon the quantity of matter contained in the substance. A cubic inch of lead will gravitate towards the earth with ten times the force of a cubic inch of cork, because the former contains ten times as much matter as the latter. In ascertaining the weight of bodies it becomes necessary to have some standard of comparison; water has been assumed as that standard, the weight of 27·72 cubic inches being called a pound; for the sake of convenience, we have substituted metallic weights instead of water.

By the *specific gravity* of any substance we mean its weight compared with the weight of the same bulk of water; let us suppose for illustration that a cubic inch of iron weighs 8 times as much as a cubic inch of water, or we will suppose that by weighing a cubic inch of iron we ascertain that it balances 2016 grains, and the same bulk of water, 252 grains. Now since the specific gravities of the two will be in proportion to their

---

What is the effect of gravity? What is *weight?* Why does lead weigh more than cork? What is the standard of comparison in ascertaining the weights of bodies? Explain what is meant by *specific gravity.* What illustration is given?

weights, if we assume 1 as the number to represent the specific gravity of water, we shall have the following proportion, 252 : 2016 :: 1 : 8.

Giving 8 for the specific gravity of iron. But it would be inconvenient and almost impossible to give to the different substances, whose specific gravities we wish to ascertain, the form of cubes, and hence it is necessary to adopt some other method by which we can ascertain, the specific gravities of bodies of irregular forms. If we can ascertain the weight of a portion of water of the same bulk as the irregular solid, we have sufficient data from which to determine the specific gravity.

If we have a rough mass of iron weighing 96 ounces, and by some means we discover that a portion of water of the same bulk weighs 12 oz. we should then obtain the specific gravity as before.

The following is the method by which we ascertain the weight of a bulk of water equivalent to that of any substance heavier than water.

If an irregular mass of marble be suspended in a tumbler even full of water a quantity of the fluid will be displaced just equal in bulk to the substance and the weight of that amount of water will be indicated by the loss sustained by weighing the article in water.

Then if a substance weighs 480 grains in the air and only 400 in water, 80 the loss, will indicate the number of grains which the same bulk of water weighs, and the proportion 80 : 480 :: 1, gives 6 the specific gravity. It will be noticed that 1 is always the third term, therefore the whole operation consists in dividing the second term by the first. Then the following steps are all that are necessary.

What number represents the specific gravity of water? How can we ascertain the weight of water of the same bulk as any given solid heavier than water? Give an illustration.

1. Weigh carefully and note the number of grains or ounces.

2. Weigh in water and subtract from the first weight.

3. Divide the weight in air by the difference of the two weights, and the quotient will be the specific gravity.

Example, A mineral weighs 525 grains in the air, and 500 grains in water; what is its specific gravity?

To determine the specific gravity of soils, take a bottle with a small neck and fill to a certain point in the neck with water, and mark the point with a file; empty a part of the water and introduce a weighed portion of the soil; after it is well mixed with the water, bring the fluid to the marked point and weigh again. The last weight will evidently be the greater, and the difference will arise from the difference of the weight of so much soil, and a similar bulk of water. This difference subtracted from the weight of the soil will give that of a similar bulk of water. Then divide the weight of the soil by this last difference, and the quotient will give the specific gravity.

To obtain the specific gravity of liquids, take a bottle of the same kind used to obtain the specific gravity of soils; introduce 1000 grains of water and mark the point to which the water rises on the neck, fill to the same point with the fluid whose specific gravity is to be ascertained and weigh; the weight will be the specific gravity considering 1000 as that of water.

Example, if alcohol be introduced into the bottle, and is found to weigh 912 grains, then 912 will be the specific gravity of alcohol, water being 1000, or ·912, water being 1.

Give the three steps for ascertaining the specific gravity? How do we ascertain the specific gravity of soils? Of liquids?

COHESIVE ATTRACTION.

This kind of attraction seems to act only when the particles of matter which it influences are apparently in contact. Hence it has been said to act at *insensible distances*, or at distances so small that they are inappreciable. It is well known that if a piece of wood be once split, the parts cannot be made to cohere again, although pressed together with considerable force, without the intervention of some other substance. It is because the particles are not brought into sufficiently close contact to induce cohesive attraction. There are solids however, which after being divided may be made to unite again by pressure.

If a lead ball be divided in the centre and both surfaces made perfectly smooth and bright, they can be made to unite by pressing the portions together with a twisting motion, the portions will adhere with considerable tenacity.

Two pieces of polished plate glass, are sometimes united by pressing their smooth surfaces together, and often so perfect is the union they can not be separated, but will be fractured at other points sooner than part at the points of union.

So long as two pieces of lead or glass, in the condition referred to, are separated by the least perceptible space, this attractive force is not exerted. Newton supposed that this attraction was limited to the distance of less than the millionth part of an inch, thus we see that whilst *gravitative attraction* acts at all distances, *cohesion* is confined to very narrow limits.

When does cohesion act? Why can not pieces of wood that have been separated, be made to re-unite by pressure? What illustrations is given of the cohesion of two pieces of lead? Give the experiment with two polished plates of glass. To what distance is the attraction of cohesion limited?

The intimate connection of the subject of cohesion and heat, renders it necessary to defer the farther consideration of this subject, until we treat of that agent.

CAPILLARY ATTRACTION.

It is this kind of attraction which causes fluids to rise above their natural level in tubes of small calibre, and derives its name from a latin word, which signifies *hair*, because the tubes have a hair-like bore. It is this kind of attraction that causes the sponge to absorb water.

In the vegetable world, we see the action of this principle in the absorption of the fluids of the earth by the plant. Most of the elements of which plants are composed, are obtained in this manner; being soluble in water they are taken up with it and are retained to form part of the plant. The body of every tree is nothing but a map of *capillary tubes*, and so of every limb and leaf. What is called the sap of the tree is the fluid drawn from the earth; this ascends to the leaves and then again descends through the bark to the earth, having parted with that which was necessary to the growth of the tree. This process, however, can not be sufficiently explained by saying that it is the effect of capillary attraction.

If a capillary tube be placed with one end in water, and the fluid be raised one inch above its natural level by lowering the tube gradually until less than an inch of the upper end is left *above* the surface of the water, it will be seen that the water will not run over the top of the tube. This experiment shows that capillary tubes will not raise water above their own extremities; yet, if we cut off the top of a vine when full of sap, the fluid

---

In what respect do gravity and cohesion differ? What is capillary attraction? What causes water to rise in the sponge? What is said of the body of every tree? Will capillary tubes raise water abeve their own extremities?

will run over the top of it, proving that something besides mere capillary attractions causes the sap to ascend the plant.

The following experiment by Draper illustrates this point.

"In the month of April, 1834, I cut a vine, which was growing wild on the edge of a forest in Virginia, asunder with one blow of an axe; the cut surface which was one and a half inch in diameter, exhibited its open vessels from which there poured out an uninterrupted stream of ascending sap. In the course of eight hours there was collected of this fluid seventy ounces, and this was probably a far less quantity than would have been raised under ordinary circumstances when the leaves aided the spongioles by their exhausting and pushing action."

Another experiment of a different character will tend to explain this cause of the flow of sap above the level to which it would be carried by capillary attraction alone. "If one end of an open glass tube be covered with a piece of moistened bladder or other fine animal membrane, tied tightly over it and a strong solution of sugar in water be then poured into the open end of the tube so as to cover the membrane to the depth of several inches, and if the closed end be then introduced to the depth of an inch below the surface of a vessel of pure water, the water will after a short time pass through the bladder inwards and the column of liquid in the tube will increase in height. This ascent will continue till, in favorable circumstances, the fluid will reach the height of several feet and will flow out or run over at the end of the tube. At the same time the water in the vessel will become sweet, indicating that while so much liquid has passed through the membrane inwards, a quantity has always passed outwards carrying sugar

---

Relate the experiment of Draper. Experiment by Johnston.

along with it. Instead of sugar, common salt gum, or other soluble substances may be dissolved in the water, and the denser this solution, the larger the quantity of water that will enter by the membrane, and the greater the height to which the column will rise.

These appearances bear a strong resemblance to those presented in the *absorption and excration* of fluids by the roots of plants. Thus, if the spongy termination of the root represents their porous membrane in the above experiment—the sap with which the tubes of wood are filled, the artificial solution introduced into the experimental tubes and the water in the soil, the fluid into which the closed extremity of the tube is introduced, we have a series of conditions precisely like those in the experiment. Fluids ought, consequently, to enter from the soil into the roots, and thence to ascend the stem, as in nature they appear to do." (Johnston.)

The cause of this ascent of fluids, both in the tree and in the experimental tube are supposed to be due to the action of two opposite currents of *electricity*, and in treating of that agent we shall refer to its action in causing the circulation of the sap.

The effect of capillary tubes upon fluids, depends upon the power of the latter to *wet* the surface of the tubes; consequently those fluids that do not wet the tube, are not raised by it above their ordinary level, but perhaps are depressed; this result follows when a glass capillary tube is plunged into a vessel of mercury. The mercury has no affinity for the glass and is not elevated by it. Water, on the same principle, is not raised by a tube having its inner surface coated with oil. We infer then that capillary attraction is caused by the affinity of the sides of the tube for the liquid which is raised.

In what respect is the plant like the experimental tube? To what is the circulation of the fluids owing? On what does the power of capillary tube to raise a fluid depend? Are fluids raised that do not wet the tubes?

CHEMICAL AFFINITY.

Chemical attraction, otherwise called chemical affinity, is that which causes substances of different kinds to unite and form new compounds, different from the substances united. For instance take a solution of chloride of calcium and unite with it a portion of oil of vitriol, (sulphuric acid.) The two liquids rapidly unite and form a white solid, familiar to all under the name of *plaster of Paris.*

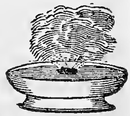
It will be well here to mark the changes that are produced in this experiment. The composition of the acid is represented by the formula SO_3, and that of the chloride of calcium Cl Ca and water, (H O,) is combined with each when in a fluid state. The sulphuric acid has a strong *affinity* for *lime,* (Ca O,) therefore calcium unites with oxygen for which it has an affinity, and the acid and base then unite to form *plaster,* (sulphate of lime) The calcium obtains its oxygen from the water, and the hydrogen released by the process, unites with the chlorine, forming muriatic acid (hydrocholoric acid.)

In this experiment we have an illustration of one of the effects of *affinity,* a solid produced by the union of two liquids: another effect is, the formation of a solid by the union of two gases, as in the process for forming carbonate of ammonia, (page 66.)

By the action of the same force two substances can be united which burst into a flame at the moment of their union, so great is the heat caused by their combination.

What is chemical affinity? What is the first illustration of its effect? Describe the changes that occur in this experiment. What results from the union of carbonic acid gas and ammonia?

Fig. 16.



An experiment of this kind is represented by Fig .16, in which the metal potassium has such an affinity for oxygen that it decomposes water for the sake of obtaining it, and the heat produced by the combination is sufficient to inflame both the hydrogen and the metal. The hydrogen in burning unites with the oxygen of the air, and thus as much water is reproduced as is decomposed by the metal.

Oxygen appears to have the greatest range of affinities of all the elements, combining with most of its fellows, and often with a single one, forming a number of different compounds. It is on account of the affinity of oxygen for iron, that water is decomposed, and hydrogen released, in the process given on page 22; the oxygen of the vapor of water unites with the red hot iron wire in the tube.

Fig. 17.

In the production of hydrogen by the action of dilute oil of vitriol upon zinc, as represented in Fig. (17,) the affinity of oxygen for the zinc, causes the union of the two and the water is thus decomposed. The sulphuric acid from its affinity for the oxide of zinc dissolves it as it is formed, and thus a fresh surface of the metal is continually presented to the oxygen. The only object of the acid is to prevent an accumulation of the oxide upon the surface, as that would put an end to the process of decomposition.

What changes does affinity produce when potassium is poured upon water? What is said of the affinity of oxygen for different elements? Why is hydrogen released in the process given on page 27? Explain the changes connected with the production of hydrogen by the process represented in fig. 17.

HEAT.

This is an all important agent in the production of those changes that are continually occurring around us. The *first effect of heat* is to expand bodies or separate their particles farther and farther from each other. We have before alluded to the intimate connection of the subject of cohesion with that of heat.

It will be seen at once that if heat has a tendency to remove the particles of matter from each other, it must in a similar degree overcome the attraction of the particles for each other, and since these forces are continually in operation, the one tending to hold together, and the other to separate the atoms of solids, it follows that cohesion and heat may properly be called *antagonistic forces*, ever opposed and each striving for the mastery. As heat is gradually withdrawn from a body, the atoms of which it is composed are drawn nearer and nearer together by the force of cohesion, yet are *never made to touch each other*. On the contrary, when heat is applied, the spaces by which the atoms are separated become larger, and if the cohesive force is sufficiently counteracted, the particles of matter of which it is composed will move freely among each other, and the solid will be changed to a *liquid*. If a still higher degree of heat be applied the particles seem to lose almost wholly the principle of attraction, and the fluid is changed to an invisible vapor. If a piece of zinc be gradually heated, the first effect will be to expand it; it will next become liquid, and eventually be changed to vapor.

Heat has much to do with the changes going on in the vegetable world; indeed all are so familiar with its influence upon vegetation that it seems hardly necessary to enlarge upon it. It is well known that the growth

---

What is the first effect of heat? What is said of the relation of cohesion and heat to each other? What effect is produced by withdrawing heat from a body?

of particular plants depends upon the temperature of the region. Wheat and barley will not flourish in the northern hemisphere farther south than the 20° of north latitude. The northern limit for wheat is 64°, of barley 80°. Height above the sea produces the same effect as a change of latitude, a height of 600 feet being equivalent to a change of 1° of latitude.

Some degree of heat is necessary to produce germination of seeds, and after this to expand the cells and pores of the plant, so as to facilitate the circulation of the sap.

The sun is the great source of heat. By this the earth is warmed during the day, and as all bodies are continually *radiating* their heat and imparting it to cooler bodies around them, in the absence of the sun the earth loses by radiation a large quantity of heat, and the temperature becomes much lower; the air lying near the surface is cooled by contact and the vapor floating in it is condensed and assumes the form of water, this deposit is denominated *dew*. If the air be sufficiently cold, this vapor will be deposited in the form of minute particles of ice and is then denominated *frost*. The cause then of dew and frost is found in the rapid radiation of heat from the earth into space in the absence of the sun. Now since all bodies radiate heat to those around them, it follows that when a mass of clouds are lying above a portion of the earth, they will radiate heat in return, and thus the temperature of the earth remaining the same or nearly so, the phenomena of dew and frost do not appear. If frost occurs while the plants are young and tender, it proves a very destructive agent. Its first injurious effect is produced by freezing the sap of the young plant, and as this must

---

State the effect of the sun upon the earth? What occurs in the absence of the sun? Explain the phenomena of dew and frost? How does a canopy of clouds prevent dew and frost? What is the effect of frost upon plants?

expands while freezing, the pores of the plant would necessarily be distended and perhaps lacerated. Yet it is contended by some that the freezing of the plant will not injure it, if it is thawed with sufficient care.—The following is a statement of their views.

"The reason why potatoes, apples, &c., become soft, and rot when frozen and then suddenly thawed, uncovered and in the open air, is the sudden *thawing*. You may put a heap of apples on the floor of a room, or other dry place, where they will freeze perfectly hard, and if covered close with anything that will exclude the air, when the weather becomes warm enough to thaw, the apples will remain sound and uninjured, after they are thus closely thawed. The cover may be of coarse tow of flax, or any article that will cover them so as to exclude the air. They may be suffered to remain so in a garret or any dry place, where it freezes hard and they will be found sound and free from injury, if the barrel remains tight till they are thoroughly thawed. It is the sudden thawing that causes the apples or other vegetables to become soft and rot. So if the fingers of your hand be frozen, and you expose them to sudden heat by warming them at the fire, and they suddenly thaw, the flesh will mortify and slough off; but if you freeze your fingers or other limbs, and put them in snow and rub gently till they thaw, or put into a pail of water just drawn from the well, which will be less cold than your frozen fingers—they will thaw slowly and suffer but little injury. So during the early autumnal frosts in September, if the morning after the frost is cloudy, the frost will be drawn slowly from the frozen vegetables, and they will be uninjured; but if they receive the rays of the early and clear sun, they thaw so suddenly, that they will hang their heads and perish.

What is supposed by some? Illustrate. What is said of a frozen hand? What is the effect of a cloudy morning after a heavy frost? The effect of a clear morning?

If wet with water from the well long enough to extract the frost before the sun shines on them, they do not suffer." (Cultivator.)

The following reasons, given by Johnston, show why the thawing and not the freezing of plants is the cause of their destruction. "When the plant freezes, the fluid portions slightly expand in becoming solid, but the air in the air vessels contracts in at least an equal degree, and thus allows a *lateral* expansion of the sap vessels sufficient to prevent injury. When the temperature is slightly raised the air expands but slightly and ice is melted long before the gaseous substances reach their original bulk. But if the rays of the sun strike suddenly upon the leaf, the surface may at once be raised in temperature 30 or 40 degrees. The air will expand suddenly, and before the sap is thawed may have distended and torn the vessels, and cause the sap and air to be mutually intermingled, chemical changes will immediately ensue, and the plant will decay."

We see then that if we would prevent the frost from accumulating upon plants, we can accomplish it by throwing over them a covering which shall operate like the clouds in a cold night in preventing it. If they have already become frozen, protect them from the rays of the approaching sun, by means of a similar covering, or by throwing cold water upon them, that they may not be suddenly thawed.

Notwithstanding the evil effects of frost, it is under other circumstances highly beneficial. It breaks up and finely pulverizes the soil during the winter months, and does it more thoroughly than could be accomplished by mechanical means. This pulverization is not accomplished during a mild winter, and there is a failure of

---

How may this be prevented? What explanation is given by Johnston? How should frozen plants be protected? In what way does frost act beneficially?

crops in consequence. The effect of frost is most obvious upon stiff clay soils, they should therefore be ploughed in the autumn or beginning of winter.

Combustion is also a source of heat. Many experiments have been described in which the union of oxygen with different substances has produced both light and heat, and it has been shown that all ordinary cases of combustion result from the union of oxygen with the burning body, hence it would be a natural inference, that combustion is produced by the union of oxygen with a body with sufficient rapidity to produce light and heat. This perhaps is the sense in which the term is generally used, but in a strictly chemical sense the definition is not broad enough, for light and heat are produced by combinations in which oxygen takes no part. Sulphur and iron will combine, under certain circumstances, and both heat and light accompany the combination: thus iron wire may be burned in a jet of the vapor of sulphur issuing from an aperture in a red hot gun barrel, but no oxygen unites with the burning body.

Combustion accompanies the union of phosphorus and iodine, for by percussion a mixture of the two is caused to burst into a flame.

Combustion then is the *evolution* of *heat and light* produced by the combination of different chemical substances. *Condensation* is sometimes given as a source of heat, but if we carefully consider the phenomena of combustion, it will be seen that they imply the process of condensation, for in all cases the result of combustion is a body either solid or otherwise, more dense than the substances united, that is, occupying less space than that occupied by the two before combustion.

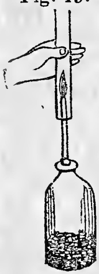
Where are its effects most obvious? What other source of heat is mentioned? From what do all ordinary cases of combustion result? Are light and heat produced by combinations in which oxygen takes no part? Illustrate.

In the combination of oxygen with carbon, producing carbonic acid, as in the combustion of charcoal in air or oxygen, the resulting gas, consisting of two proportions of oxygen and one of carbon, fills only the space before occupied by the oxygen alone, the two elements, therefore, have been condensed in the act of combining: the space before occupied by 11 grains of oxygen, contains after combustion, 15 grains of carbonic acid.

Fig. 18.

In the ignition of iron wire in oxygen gas, all the oxygen unites with the iron, and many cubic inches of the gas, are condensed in each of the melted globules that fall from the wire; here we see the reason why so great a degree of heat is produced in this experiment, the intensity of the heat is proportioned to the rapidity and extent of the condensation. A similar result is produced in the combustion of phosphorus in oxygen; a large volume of gas and a portion of phosphorus are condensed in a small quantity of phosphoric acid.

Fig. 19.



In the production of musical tones as represented in (Fig. 19,) the hydrogen generated in the bottle and burned at the end of the tube, unites with the oxygen of the air, and produces water: this will be indicated by the accumulation of vapor on the inner surface of the tube. Here we have a great degree of heat, produced by the rapid conversion of two gases into a liquid.

If oxygen and hydrogen be conveyed by separate tubes to a common jet, and the mixture inflamed, the combination of the gases, produces a

Give the definition of *combustion?* What is the result of ordinary combustion? The space occupied by 11 grains of oxygen before combustion, contains how many of carbonic acid afterwards? What degree of condensation occurs in the *combustion* of iron in oxygen? What is the cause of the heat in the experiment represented in Fig. 19?

most intense heat. The apparatus arranged for this purpose is called a *compound blowpipe*, and by means of it the most refractory substances are fused. Platinum, silica, and other substances that are utterly infusible in any furnace, are readily melted in the oxyhydrogen flame. In this experiment, as in the last, the intensity of the heat is owing to the amount of gaseous matter that is rapidly converted into water; the effect is greater in the latter case because oxygen and hydrogen unite with greater rapidity than in the former; in this union 2000 cubic inches of the gases form but 1 cubic inch of water, and the combination is rapidly effected.

We may state as a general principle, that a like degree of condensation ever produces a like degree of heat, that is, in the union of the same substances; thus the formation of a certain amount of carbonic acid, by the union of carbon and oxygen, always produces a fixed amount of heat, and a pound of carbon, as we have already asserted, produces the same degree of heat, when consumed in the process of respiration, as when burned in a coal fire; the same condensation must take place, whether the union is accomplished in a longer or shorter space of time. The process by which the carbon of the blood is consumed, is strictly a kind of *combustion*, although unaccompanied by any sensible *light*; yet who can say that light is not produced. The slow combustion of phosphorus, as it occurs when that substance is exposed to the air, produces both heat and light, but the heat is not appreciable and the light is not seen in open day; yet this is plainly a process of combustion.

In the spontaneous rusting of iron, there is as much oxygen condensed, as when the metal is burned in the

---

Explain the principle upon which heat is produced by the compound blowpipe? What substances are fused by it? State the degree of condensation produced. What general principle is stated? What is said of the heat produced by respiration?

pure gas. Does it not follow then, that just as much heat is produced in the former case as in the latter? May we not even suppose the same degree of *light* to be really evolved in the rusting of iron as when it is brilliantly ignited in oxygen? Light is often given out by bodies, when we do not perceive it. It has been seen radiating from the poles of a magnet; not however, by persons in health, but by individuals, afflicted by a certain disease that rendered the optic nerve remarkably sensitive, and enabled them to detect the presence of light where none could be perceived by others.

We may safely conclude, that in all cases of combustion, there is a degree of condensation, commensurate with the heat produced, and that the same degree of condensation, in the union of any two substances is ever accompanied by the evolution of a like degree of heat and light.

We have seen that the effect of caloric* is to remove the atoms of which bodies are composed, farther from each other, that is, the particles of matter, which are never in contact, make room, so to speak, for the heat which enters the body. If then in the act of expanding, bodies absorb heat, we should naturally expect, that whenever bodies by any means are rendered more dense, a certain amount of heat will be given out; for their particles are by this means brought nearer each other and the heat must be expelled. This also may be observed, that, whenever bodies expand without the application of heat, there is still just as much heat taken up, as when it is directly applied. If ice be melted by

* The terms *heat* and *caloric* are used synonymously.

Is light often produced when we are not able to perceive it? What illustration is given? What may we conclude with regard to all cases of combustion?

uniting with it substances that have a great avidity for moisture, and without applying heat, there still will be as much caloric absorbed, as when the ice is melted over the fire, and this heat must be taken from surrounding objects. It is well known that common salt and pounded ice combined, form a *freezing mixture*, and substances surrounding a vessel containing these, are solidified by the cold produced : this result is caused by the rapid liquifaction of the two solids without the application of heat.

The heat that enters the ice and salt, is said to be *latent*, because the temperature of the mass is not raised until it has all become liquid, although caloric is rapidly absorbed every moment. A more striking instance of the effect of liquifaction is exhibited in the mixture of sulphate of soda (Glauber's salt) and muriatic acid, eight parts of the former to five of the latter; the Glauber's salt immediately assuming the liquid form, a large quantity of caloric is absorbed from surrounding objects, and a sufficient degree of cold is produced to freeze water contained in a tube placed in the mixture.

The amount of heat that becomes latent in such cases, depends upon the quantity of solid matter that is liquified in a given time.

If liquifaction necessarily implies the absorption of caloric, then must vaporization produce a similar effect, only in a greater degree, for when a liquid is converted into vapor, the particles become far removed from each other, and much heat must enter and exert its repulsive power in keeping the atoms apart.

The most common illustration of this effect, is to pour alcohol or ether upon the hand and notice the cold pro-

---

When bodies expand without the application of heat what follows? Common salt and pounded ice form what? Why? What is said of the heat absorbed? Why? Give another method of forming a freezing mixture. Why is such a degree of cold produced? What determines the amount of heat that becomes latent?

duced by the rapid evaporation. If water be rapidly converted into vapor without the application of heat, so much caloric will be rendered *latent*, that the water will be frozen. This may be illustrated by placing water under the receiver of an air pump, in a vessel well coated with lamp-black, that caloric may not be conducted to the fluid; by exhausting the receiver, a rapid evaporation takes place from the surface of the water, and the heat rendered latent being taken from the fluid, the latter is converted into ice.

There are many interesting points connected with the phenomena of heat, upon which we can not dwell in a work thus limited in its nature. Of electricity as a source of heat, we shall speak when treating of that agent.

ELECTRICITY.

It was discovered by the ancients, that if amber was rubbed with woolen cloth, silk, or similar substances, it became possessed of the property of *attraction*, and light substances would adhere to it. This property, which is also capable of being induced in rosin, sealing wax, silk, &c., is owing to the presence of *electricity*. It is not necessary here to describe minutely all the phenomena connected with the manifestations of this force, and we will give merely an epitome of the most common.

If a dry and warm tube of glass be rubbed briskly with a silk handkerchief, and then be immediately presented to a pith ball, suspended by a silk thread, the ball will quickly attach itself to the tube, but in a short time will be thrown back, and the two

---

What is the effect of converting a liquid to vapor? Illustrate. State the effect of the rapid evaporation of water under the receiver of an air pump. State the effect produced by rubbing amber with silk. To what is this effect owing?

will mutually repel each other. In this experiment the pith ball becomes *electrified* or charged with electricity. If two balls be thus effected they will repel each other, and will have the power of attracting substances not electrified. If the pith balls be suspended by wire, no matter how fine, they will not remain electrified except while connected with the tube. The glass rod, whilst excited, exhibits a phosphorescent glow in the dark, and if the electricity be differently accumulated, an electric spark will leap from the surface of the tube to the hand presented to it. If a rod of metal, instead of glass, be rubbed in the same way, no electrical effects will be produced.

These are the principal phenomena connected with electricity; attraction, repulsion, electrical light and the spark.

To explain these we will suppose, in accordance with the theory of Dufay, that there are two kinds of electricity, and bodies in their ordinary state, contain the two in a state of equilibrium, but by friction the equilibrium is destroyed in certain substances, such as glass, rosin, &c., and an accumulation of one kind of electricity or the other, is produced. By friction a glass tube becomes charged with a kind of electricity called *vitreous*, or *positive*, whilst rosin by the same means is thrown into a different state, and the electricity is called *resinous* or *negative*. If two pith balls be electrified, one by excited glass, the other by rosin, they will attract each other, but if both be charged from the same substance, they will mutually repel, as has been stated. From this experiment we draw the inference that *bodies in the same electrical state repel, and those in different states attract each other.*

State the different phenomena exhibited by means of an excited tube. What is said of bodies in their ordinary state ?

We see by this why a light substance is first attracted to the excited tube and then repelled. Glass, rosin, and all those substances that can be excited in a similar manner are called *electrics ;* the term *non-electrics* is applied to those substances, that can not be excited in a similar manner, although even these can be excited when properly arranged: the metals and many other substances belong to this class.

When electricity accumulates upon the surface of an electric, it is retained and not allowed to escape, although it has a great tendency to do so, the electrics are, therefore, called *non-conductors.* The non-electrics on the contrary allow the free passage of electricity from themselves to other bodies, they are therefore denominated *conductors.* Electricity does not remain upon a pith ball suspended by a wire, because it is immediately conducted away by the metal, unless some non-conductor intervene; when silk is used to suspend a ball, the fluid is prevented from passing away, because this substance is a non-conductor.

We can not here go into an explanation of the different kinds and forms of apparatus calculated to illustrate the phenomena of electricity, but must confine ourselves to those principles, a knowledge of which is necessary, to an understanding of the agency of electricity in producing the organization of plants.

That electricity exerts an important influence upon vegetation, can not be doubted, but the manner of its action is difficult of solution. We have before alluded to the fact that the ascent of sap in the living plant, is in part, owing to electricity. The following experiment

---

What name is given to the electricity derived from glass? From rosin? What is said of bodies in different electrical states? In like electrical states? What are electrics? Non-electrics? Conductors? Non-conductors? Does electricity exert any influence upon vegetation? In what way?

will tend to confirm this theory. Let a capillary tube bent in the form of a syphon be filled and connected with a vessel of water. The fluid will pass over slowly drop by drop: and while the water is being drained out, connect it with the prime conductor of an electrical machine, or by some means charge it with electricity, and the fluid will commence running freely from the capillary tube. This serves to prove that the presence of electricity facilitates the passage of fluids through porous substances, and consequently may quicken the circulation of sap in the plant, and make vegetables more vigorous and healthy. It is in the power of the agriculturist to increase electrical action upon a limited portion of the surface of the earth, but this principle can not economically be applied except on a small scale, as in the rearing of house plants, or the cultivation of garden vegetables. The mode of nourishing plants by electricity however depends upon a different modification of this force, and a short explanation of its peculiarities will be given.

Galvanic Electricity is generally excited by the action of acidulated water upon metals of different kinds; for instance, if a small plate of copper and a similar one of zinc, be immersed in very dilute acid, electricity will be generated, and the positive fluid will flow from the metal most easily oxidized to the other; this will occur however, only when the ends of the plates not immersed are connected, in that case the flow of electricity, is as stated before, from the zinc to the copper in the fluid, but from the copper to the zinc again out of the fluid, thus restoring the equilibrium.

If the zinc be pure, there will be no unusual action, except when the two plates are connected. As soon as a communication is established between them, bub-

---

Give the experiment with a capillary tube. What does this prove? How is galvanic electricity excited? How must the plates be arranged?

bles of hydrogen begin to accumulate upon the copper, and the zinc is rapidly oxidized; the oxide is dissolved by the acid as it is formed, and electricity flows along the connecting substance. Non-conductors of electricity must not be used for connecting the plates; but copper or brass wire, or some other good conductor should be made the medium of communication. Two conducting wires, one connected with each plate, form the *poles* of the generating pair.

If a fine wire of platinum be made the connecting substance, and the plates used are of sufficient size, the effect of the electricity will be to elevate the temperature of the wire, until it becomes red hot: thus we see that electricity is a source of heat, and it is not only so with galvanic electricity, but the electricity drawn from a glass tube by friction may be made to fuse the different metals.

Copper and zinc arranged as has been described, form what is called a *Voltaic circle*, and the electricity generated arises from the decomposition of water, the hydrogen of that compound passing to the copper, and the oxygen to the zinc. If several Voltaic pairs be united by connecting the zinc of one with the copper of the next and so on, having the poles connected with the extreme copper and zinc plates, the intensity of the current will be increased. To this form of apparatus the term *battery* is applied, although a single pair is sometimes called by the same name.

If the poles of a battery of four or five pairs are immersed in a vessel of water, the decomposition of that fluid is effected, and the hydrogen passes to the negative pole, or that connected with the zinc, and rises in minute

---

What is the effect when the two plates are connected? What are the *poles* of a galvanic pair? Give the effect of electricity upon platinum. From what does the electricity arise? What becomes of the oxygen and hydrogen of the water? How may the intensity of the current be increased? What is the effect of a small battery upon water?

bubbles to the surface; the oxygen in a similar manner is disengaged at the positive pole; the poles should be pointed with platinum or gold.

These phenomena are explained by supposing that the elementary atoms of which water is composed, are in opposite states of electricity, and therefore, the hydrogen being positive passes to the negative pole, but the oxygen being negative is attracted to the positive. Different compounds are decomposed on the same principle. Potash subjected to the action of a powerful battery, yields its oxygen to the positive pole, and the metal potassium is collected at the other. Soda suffers a similar decomposition, and the metals sodium and potassium were first obtained by means of the galvanic battery. The metals pass to the negative pole, but oxygen, chlorine, sulphur, &c., are attracted by the positive.

Many batteries, differing in form and power, have been constructed, the most simple and efficacious of which, is that invented by Professor Grove of London. The metals used are platinum and zinc; the latter is coated with mercury, because the metal is impure, and by amalgamating it, the rapid solution of it in the acid which would otherwise take place, is prevented, and the galvanic action is more uniform and constant. A small thin slip of platinum is used and is acted upon by strong nitric acid, but as this acid would be too strong for the zinc, the two metals are arranged in different cups and acted upon by separate fluids; the cup containing the platinum is of porous earthenware, and is placed within the other, which may be an ordinary glass tumbler; in the latter is placed a coil of amalgamated zinc which is acted upon by dilute sulphuric acid. The porous cup permits the free passage of electricity but does

---

Give an explanation of the changes that occur. Give the effect of the battery upon potash, soda. How were potassium and sodium first obtained? Describe Grove's battery. Why is a porous cup used?

not allow the fluids to intermingle to any great extent.

Here, as in the first form of the battery, the electric force arises from the decomposition of water; the oxygen passes to the zinc as before, but the hydrogen does not collect upon the platinum plate as it does upon the copper in the other battery, but passing into the nitric acid, decomposes it; uniting with a part of its oxygen and causing an evolution of deutoxide of nitrogen.

It has been before suggested that galvanic electricity has been applied to growing plants. A single pair of copper and zinc plates is generally applied. It is not necessary that any particular fluid should be employed for exciting galvanic action; it is only important that it have the power of oxidizing the zinc Moisture will produce the requisite effect and moist substances, forming a communication between the plates will excite a voltaic current. If therefore a large plate of copper and a similar one of zinc be imbedded in moist earth, facing each other, and connected together by means of a copper wire which passes through the air and is soldered to each, an electric current will be generated which must pass through the intervening earth, and influence the growth of vegetable forms that occupy that space. It is in this way that electricity is applied to hasten the maturity of plants. The favorable action of electricity upon vegetation is perhaps in part owing to its decomposing power; indeed it is quite probable that the different compounds taken up by the plant are decomposed by a kind of electric force residing in the plant, and thus the different elements are assimilated; if so the reason is apparent why vegetation is assisted by the application of galvanic electricity.

How are plants acted upon by galvanic electricity? To what may the favorable action of electricity upon vegetation be owing?

LIGHT.

Light was formerly supposed to be occasioned by the emanation of minute particles of matter from the sun, but this theory has been abandoned, and it is now generally conceded that there exists a subtile elastic medium which is thrown into vibrations by the presence of the luminous body.

Light is a powerful chemical agent and although silent in its operations is continually promoting chemical changes. It is essential to the perfection of vegetable forms, and is supposed to be necessary to the health of the animal frame. It is sometimes said to be composed of seven colors, *violet*, *indigo*, *blue*, *green*, *yellow*, *orange*, and *red*, because by means of a *prism* we can produce these several colors from a single ray of white light; yet strictly speaking this elastic medium of which we have spoken can not be said to be composed of different colors. The waves of light produced by the vibration of the medium have been found to be of different lengths, according to the colors displayed, and thus different shades of color are produced in much the same way that different musical sounds are caused by difference of vibration in the medium of communication.

In the vegetable world the various changes necessary to produce a healthy plant can not occur without the presence of light. During the day carbonic acid gas is absorbed by every green leaf, but during the night this process, which is so necessary to the perfection of the plant, does not continue. Plants will grow to some extent in the shade or even in a dark cellar, but they are pale and sickly; the bright green color can not be pro-

What was formerly supposed with regard to light, and what is now conceded? What is said of it as a chemical agent? How many colors are exhibited by the decomposition of light? To what are they owing? What process goes on during the day in the leaves of plants? How is it during the night?

duced but by the influence of light. The leaves of some plants follow the sun in its course. and it is a well known fact that growing vegetables stretch their foliage in the direction whence most light is received. It will be noticed that the trees lining roads which pass through the forest, have the greater share of their foliage stretching towards the opening caused by the road.

The means by which the plant is supplied with carbon have been pointed out; but carbonic acid after it has been absorbed by the leaves, must be decomposed by light, otherwise no carbon will be assimilated. The changes that occur by day in vegetable forms may be illustrated, by placing some green leaves in a vessel of spring water, and placing it inverted in a second vessel containing water. (See Fig. 20.)

Fig. 20.

If the leaves be exposed to the action of sunlight, small bubbles of gas will rise from them and collect in the upper part of the vessel. By examination it will appear that the carbonic acid which was dissolved in the water has been taken up by the leaves, decomposed by the action of light, and oxygen given off.

The agency of light in producing the organization of plants has been distinctly shown by the researches of Dr. Draper. The following extracts will illustrate his views.

" Organized beings, and organized bodies spring forth in those positions only to which the rays of the sun have access. They are, therefore limited to the atmosphere, the sea, and the surface of the earth. Periodical vicissitudes, which are observed both in vegetables and in animals, serve to show that this is not a mere fortuitous coincidence, but rather an intimate connection between

---

State facts showing the influence of light upon plants, trees, &c. State the experiment given.

the phenomena of life, and the presence of the imponderables. When the sun is set, the leaves of plants no longer decompose the carbonic acid of the air, but a pause takes place in the activity of their functions, and they sink into a passive condition. The gaseous bodies brought from the ground by the action of the spongioles percolate through the delicate tissues of the leaf, and escape away into the atmosphere. At night, also, in many flowers, the petals fold themselves together, and, for a time, all active processes cease."

"The general principles of life carried on in the water are modelled on the same idea as in the case of life carried on in the air. In both cases, vegetables act as the great formative agents, and animals as the destructive power; and in both, the source and origin of action is to be found in the beams of the sun. For nearly two centuries, physical science has fully admitted the agency of that central star, as the great seat of mechanical force, which retains the different planets in their orbits. It is only of late years that we are beginning to recognize his agency as the author of organization and life, who lays up, with an almost provident foresight, in vegetable productions, stores of light and heat for the use of the animal world. The coal fields which furnish us with fuel are the remains of primeval forests, among the branches of which, birds nestled at night; and the warmth that we receive from them, and the light that they give us, have been safely stored up for us for thousands of centuries. Those little insects, also, which at certain seasons cause the sea to shine with a phosphorescent light, derive their glow remotely from the vegetable kingdom: and the fire flies which, in such countless multitudes, on a summer evening in Virginia, make the grass and trees glitter with their inter-

---

What does Draper say of the leaves of plants after sunset? What of the great influence of the sun? Of phosphorescent insects?

mitting beams, are only pouring forth again rays which once came from the sun."

"If a few garden seeds of any kind are sown in a flowerpot, and caused to germinate in a dark room, after a while it will be perceived that they can grow for a certain space in the absence of light; their young leaves, if any should be put forth, are of a yellow or gray-white color, and they soon fade away and die. But if these plants be brought out into the light, they presently begin to turn green, they unfold their leaves, and evolve their different parts in a natural way. From day to day their weight increases, and chemical analysis shows that they are fixing carbon, hydrogen, oxygen, and azote, (nitrogen.) If they be made to grow in confined glass vessels, under such circumstances that an examination can be instituted on the changes they are impressing on the atmosphere, it is discovered that they are constantly abstracting carbonic acid from it, and as long as the sun shines on them, or as long as they are exposed to bright daylight, they continue appropriating carbon and exhaling a mixture of oxygen and nitrogen. The continuance of their growth depends on a continued supply of the acid gas in due quantities. The leading facts which are here mentioned were discovered during the last century by Priestly, who found that when leaves of any kind are placed in water, which holds carbonic acid gas in solution, they evolve oxygen when in the sunshine. It is not pure oxygen, but a mixture of that gas with azote."

The last remark seems to be introduced, because it is generally stated that *pure oxygen* is given off by the growing plant, while not only this but nitrogen and even carbonic acid are thrown off in minute quantities during

---

What is said of plants growing in the dark? What changes are impressed upon the air by plants exposed to sunlight? What is generally said to be given off by the plant?

the decompositions that take place in the tissues of the plant. The water of the vegetable structure has the power of absorbing all these gases, but in different quantities; nitrogen is slowly absorbed, oxygen more rapidly, and carbonic acid with still greater facility, and in the decomposition produced by sunlight, all are released, but principally oxygen; the last mentioned gas, however, may not be derived wholly from the carbonic acid, for there are strong indications that light not only decomposes this acid but water itself, and since, as we have before stated, there is an excess of hydrogen in most plants, a portion of oxygen derived from water probably escapes. The author from whom we have just quoted, has endeavored to determine the kind of light which is most active in producing the requisite decompositions. By investigating the subject he has determined that of the four distinct principles of which light is made up, viz. *calorific*, *tithonic or chemical*, *phosphorescent* and *luminous* rays, the latter are principally concerned in the decomposition of water, and carbonic acid in the plant. The following are some of his arguments and experiments tending to prove his position.

"First let us ascertain whether radiant heat, generally, has the quality of producing decomposition. To rays coming from a brightly-burning fire, I exposed some vegetable leaves in water holding carbonic acid in solution, and, to increase the effect converged the calorific rays by a large metallic concave mirror. That no doubt might remain of the incapacity of heat to produce the phenomenon, the temperature of the water, under the influence of the radiant heat was allowed to run up to 140° Fah., a much higher point than is ever attained under natural circumstances. But neither at low temperatures, nor at these elevated ones, did any

---

Are other gases evolved? Name them. Is the oxygen thus evolved derived wholly from carbonic acid? From what else?

visible decomposition take place; showing thus, that heat alone can not cause the digestion of plants. Moreover, as is well known to chemists, carbonic acid gas may be passed through a tube that is white hot, without giving the most remote appearances of decomposition."

Other experiments seemed to indicate, that the heat of the different colored rays, did not produce the required effect.

"That the decomposition of carbonic acid by leaves is not due to yellow heat, may be proved by causing the active light to pass through a solution of bichromate of potash, which is of an orange-yellow color. This ray, thus treated, appears to carry on the decomposition with nearly the same activity as the direct solar beams. In an experiment which I made, using it in a stratum of certain thickness, it seemed to transmit the yellow and orange light with very little loss; but acting more energetically on the calorific ray, it transmitted of it only ·26. Had this heat been the cause of the decomposition, the rapidity with which the action took place should have been proportionally reduced.

From such results, it is to be inferred that radiant heat generally, and the yellow rays of heat especially, do not produce the decomposition of carbonic acid gas in the structure of vegetable leaves.

This narrows the question down to the inquiry, whether it be the yellow ray of light, or the yellow tithonic ray; for, as has been observed, the phosphorescent rays may be left out of the discussion."

That which is called the *tithonic ray*, by this author has heretofore been denominated the *chemical ray*, on

---

By what experiment is it shown that radiant heat does not produce the decomposition that takes place in the tissues of the plant? State the experiment with the heat of the yellow ray. What is the tithonic ray referred to?

account of its agency in producing chemical combinations. It is this ray which destroys colors in the process of bleaching, and the same principle occasions the explosive combination of hydrogen and chlorine in the experiment given on page 51. It is a curious fact that the *luminous* power of light may be wholly destroyed by passing it through certain substances, while its *chemical* power is unchanged.

It is well known that the diamond after being exposed to the sun, will be seen to give out light when carried into a dark place. To the rays thus absorbed and afterwards given out, the term *phosphorescent* is applied.

The experiments of Draper last referred to, were made with the yellow rays; they had been proved before to be most active in aiding vegetable organization, but it was still a question, whether the result was produced by the calorific, chemical, or luminious ray of the yellow light. A solution of the bichromate of potash was found to diminish the force of the chemical ray when light was passed through it, so much so, that the rays thus treated effected very slowly those substances that are under ordinary circumstances rapidly decomposed by the chemical ray. Yet the yellow light produced by such a solution, caused a rapid decomposition of carbonic acid when the plant was under the influence of it. From all the results obtained by experiment, the inference is that "*to the light, and more especially to the yellow light of the sun, we are to impute the most interesting phenomena of organic chemistry.*"

In this connection it may be well to reconsider the phenomena connected with capillary attraction since light controls the movement of the sap to a great extent, and determines the rapidity of the circulation.

State the chemical effects of this ray. What are phosphorescent rays? What was the effect of a solution of bichromate of potash upon the chemical ray of yellow light?

It is well known that a porous substance will be more easily penetrated by some fluids than by others. Weak alcohol may be concentrated by putting it into a bladder, and permitting the water to pass through the pores, the alcohol will be retained, because it does not easily pass through the porous membrane. If a bladder filled with alcohol and tied perfectly tight, be placed in a vessel of water, the two liquids will intermingle, the water in the vessel will be found by examination to contain alcohol, and the water without will slowly pass into the bladder; these effects are due to the action of the *capillary* force, for if two different fluids be permitted to communicate through a capillary tube, or a porous membrane which is made up of an infinite number of such tubes, a current will be established in each direction, and there will be a gradual intermingling of the two. If one of the fluids employed has a tendency to pass through the porous substance more rapidly than the other, the result will be an accumulation of fluid, on one side of the capillary division, and a diminution on the other. As a result of the action of this principle, the bladder in the experiment just given, is distended and finally bursts, because the water passes in with greater rapidity than the alcohol passes out. A similar illustration is given in the remarks on capillary attraction.

The passage of gases through a membrane illustrates the same principle; if a piece of India rubber be tied over the mouth of a jar, so tightly, that there can be no communication except through the pores of the covering, and the vessel be placed under a bell-glass filled with ammonia, the ammoniacal atmosphere will pass into the vessel so rapidly, as to distend considerably the

---

How may water be separated from weak alcohol? Describe the effect of immersing a bladder of alcohol in water. Why is there an accumulation within the bladder? What experiment illustrates the similar passage of gases through a porous membrane?

elastic coveiing. Draper has discovered that "sulphurous acid will pass into atmospheric air against a pressure of one hundred and ten pounds on the square inch, and sulphuretted hydrogen will move through a membrane with a force that is superior to a pressure of twenty-four atmospheres."

By appplying the principle thus elicited by experiment, the true cause of the circulation of the sap in the plant in both directions is made evident. The sunlight by its decomposing action upon the carbonic acid dissolved in the sap of the leaf, changes the nature of that liquid, charging it with carbon and perhaps an excess of hydrogen ; thus the plant is supplied with two fluids, and all the conditions are fulfilled that occasion the passage of liquids in different directions through capillary tubes. Light then by its action, produces the condition necessary to the exertion of the capillary force.

Allusion has been made to the similarity of action in many respects of the different chemical forces, and it seems not improbable that capillary attraction is only a modification of electrical attraction. The tendency of all late researches with regard to the different chemical forces, has been to show new similarities and to bring them nearer and nearer together.

What is said of sulphurous acid and sulphuretted hydrogen ? What effect does light produce upon the sap of the plant ? Capillary attraction may be a modification of what ?

PART V.

FERTILIZERS.

MINERAL, ANIMAL, AND VEGETABLE MANURES.

Preliminary Observations.

Seed time and harvest are promised to the tillers of the soil, but this is not an unconditional promise. Man may not fold his arms, and in sleep await the growing grain and ripening harvest, and still expect the blessing. Experience has taught him that unless nature's requisitions be complied with, unless the earth be fitted to receive the seed and the germ of future plants be properly consigned to it, no harvest will ensue. The various forms of the vegetable world-like animal existence, require food, drink, and an atmosphere fitted to their wants; these are amply supplied where nature is her own husbandman, for she faithfully returns to the earth what she has withdrawn from it, even returns much more than she has received. The mighty oak gathers its strength from the earth and air, but after having withstood the shock of many a tempest and passed through the various changes of springtime freshness, and autumnal blight; it falls and mingles with the dust from which it sprang; thus returning, with interest, the atoms gathered from the earth.

The forest trees, made up in part of the inorganic matter of the soil, when they sink to earth, bear with them a mass of atoms that once floated in the atmosphere. Thus it is that, unassisted by art, the soil upon which the forests stand does not become impoverished, but on the contrary increases in fertility each succeeding year. The dark rich mould accumulatiug upon the surface is mostly gathered from the air and this gives new vigor to each successive growth. But not so in the fields whence man continually draws the necessaries of life and the sources of wealth and enjoyment. The earth yields of its substance to each growing plant that is cultivated by man, and every crop removed, in a measure weakens and exhausts the soil. Thus it follows that, however rich a soil may be, continued cropping, without a corresponding return in some available form, will produce barrenness.

The plant just as imperatively demands food, and that of a kind adapted to its nature, as does the animal system, yet if we may judge from the practice of many of the tillers of the soil, there is not that knowledge or appreciation of the wants of vegetable life, which the importance of the subject demand. It seems to be often forgotten by agriculturalists that vegetable forms, can not be produced in the great laboratory of nature unless there be a supply of the *raw materials*. Too much faith is manifested in the ability of nature to create from *nothing* those forms so necessary to the existence of all living beings. The materials of which plants are formed and the sources from which they may be derived have been pointed out. A general examination of the efficacy of the different fertilizers, that can be economically applied by the agriculturalist, will now be given.

SECTION I.

MINERAL MANURES.

Lime.

If we examine the ashes of plants, a portion, and in some cases a large portion of lime will be found. It is therefore evident that a certain proportion of this substance is essential to perfect vegetable organization, and should be contained in the soil. Most soils contain some lime, because they are formed by the disintegration, or wearing down, of the different rocks, and many of these contain this mineral; in many localities it occurs in mountain masses nearly pure and in inexhaustable quantities.

The term *lime*, in a chemical sense, applies only to the burned lime before it has been slacked; after being slacked it is a *hydrate* of lime; by exposure to the air this become gradually changed to a *carbonate* and in this condition has the same chemical constitution as when taken from the quarry; the term *lime* however, will be indiscriminately applied to the various forms mentioned, the term *quicklime* being used to designate the unslacked whenever it is necessary to do so.

The importance of this mineral as a manure, by no means depends wholly upon the demand of the plant for lime as food; in numerous ways it facilitates the process of vegetation, and aids in the production of vegetable forms.

1. A certain amount differing in different plants is all essential to the perfection of the vegetable structure.
2. The action of lime upon the vegetable matter in the soil renders it fit to supply nourishment to the plant.

Does lime occur in the ashes of plants? What effect is produced upon lme by slacking? By exposure to the air? In what different ways does lime promote vegetation?

3. Lime seems to neutralize noxious compounds, destroys useless weeds and coarse grasses; and expels worms and insects that infest the soil.

4. The stiff, clayey soils are, by the application of lime, rendered loose and porous, less retentive of moisture and therefore warmer, and made to release ammonia which is often held with great tenacity by such soils.

Lime as a source of nourishment, probably exerts a less important influence, than as an agent through which the soil and vegetable manures are fitted to promote vegetation. Yet many plants require no inconsiderable share of food in the form of lime, as will be indicated by the following table given by Johnston. The average produce of an acre of land, under the following crops, contains of lime—

	Grain, or roots.	Straw, or tops.	Total.
Wheat, 25 bushels,	1·5	7·2	8·7 lbs.
Barley, 38 "	2·1	12·9	15 "
Oats, 50 "	2·5	5·7	8·2 "
Turnips, 25 tons,	45·8	93·0	138·8 "
Potatoes, 9 "	6·6	259·4	266·0 "
Red clover, 2 "	——	126·	126· "
Rye grass, 2 "	——	33·	33· "

On account of the amount of lime in the ashes of certain plants, they are called *lime plants*, but it is a curious and somewhat important property of some of these, that potash may be made to take the place of lime. This is the case to a certain extent, with the tobacco plant, which is generally ranked among lime plants, but has been so cultivated as to assimilate more potash than lime, thus producing a more valuable article of tobacco.

Show something of the different quantities of lime withdrawn from an acre of land by different crops? What are those plants called that contain a large quantity of lime? What may take the place of lime?

Action of Lime upon Vegetable matter.

The mode in which *caustic* lime produces the requisite changes in vegetable matter contained in the soil, is thus stated by the author last quoted.

"In the presence of air and water, when assisted by a favoring temperature, vegetable matter, as we have already seen, undergoes spontaneous decomposition. In the same circumstances lime promotes and sensibly hastens this decomposition; altering the forms or stages through which the organic matter must pass; but bringing about more speedily the final conversion into carbonic acid and water. During its natural decay in a moist and open soil, organic matter gives off a portion of carbonic acid gas, which escapes and forms certain other acids which remain in the dark mold of the soil itself. When quick or slacked lime is added to the land, its first effect is to combine with these acids—to form carbonate, humate, &c., of lime—till the whole of the acid matter existing at the time is taken up. That portion of the lime which remains uncombined, either slowly absorbs carbonic acid from the air or unites with the carbonate already formed, to produce the known compound of hydrate with carbonate of lime,—waiting in this state in the soil till some fresh portions of acid matter are formed with which it may combine. But it does not inactively wait; it persuades and influences the organic matter to combine with the oxygen of the air and water with which it is surrounded, for the production of such acid substances—till finally the whole of the lime becomes combined either with carbonic or with some other acid of organic origin."

"Of the saline compounds which caustic lime thus forms either immediately or ultimately, some, like the

---

State the effect of lime upon decomposing vegetable matter. What does it first combine with? What is said of the insolubility of the different compounds formed?

carbonate and humate, being very sparingly soluble in water, remain more or less permanently in the soil; others, like the acetate of lime, being readily soluble, are either washed out by the rains or are sucked up by the roots of the growing plants. In the former case they cause the removal of both organic matter and of lime from the land; in the latter they supply the plant with a portion of organic food, and at the same time with lime—without which, as we have frequently before remarked, plants cannot be maintained in their most healthy condition."

"The main utility of lime depends upon its prolonged after action upon the vegetable matter of the soil. What is this action, and in what consist the benefits to which it gives rise?

In answering this question, it is of importance to observe that all the effects produced by alkaline matter in general—whether by lime or by potash—in the caustic state, are produced in *kind* also by the same substances in the state of carbonate. The carbonic acid with which they are united is retained by a comparatively feeble affinity, and is displaced with greater or less ease by almost every other acid compound which is produced in the soil. With this displacement is connected an interesting series of beautiful reactions, which it is of consequence to understand.

You will recollect that the great end which nature, so to speak, has in view, in all the changes to which she subjects organic matter in the soil, is to convert it—with the exception of its nitrogen—into carbonic acid and water. For this purpose it combines, at one time, with the oxygen of the air, while at another it decomposes water and unites with the oxygen or the hydrogen which are liberated or with both to form new chemical

---

Is the same effect produced by the carbonate as by the caustic lime? Into what is organic matter mostly converted?

combinations. Each of these new combinations is either immediately preliminary to or is attended by the conversion of a portion of the elements of the organic matter into one or other of those simpler forms of matter on which plants live. Now during these preliminary or preparatoay steps, acid substances, as I have already explained, are among others constantly produced. With these acids, the carbonate of lime, when present in the soil, is ever ready to combine. But in so combining it gives off the carbonic acid with which it is already united, and thus a continual, slow evolution of carbonic acid is kept up as long as any undecomposed carbonate remains in the soil.

The changes, therefore, which lime and organic matter, supposed to be free from nitrogen, respectively undergo, and their mutual action in the soil, may be summed up as follows:—

1. The organic matter, under the influence of air and moisture, spontaneously decomposes, and besides carbonic acid which escapes, forms also other acid substances which linger in the soil.

2. With these acids the quick-lime combines, and, either by its union with them or with carbonic acid from the air, soon (comparatively) loses its caustic state.

3. The production of acid substances by the oxidation of the organic matter—goes on more rapidly under the disposing influence of the lime, whether caustic or carbonate. These acids combined with the lime, liberating from it, when in the state of carbonate a slow but constant current of carbonic acid, upon which plants at least partly live.

4. The organic acid matter which thus unites with the lime continues itself to be acted upon by the air and

---

What is the effect of the acids in the soil upon the carbonate of lime? What is given off? State the different changes produced by lime and organic matter?

water, aided by heat and light, itself passes through a succession of stages of decomposition, at each of which it gives off water or carbonic acid, retaining still its hold of the lime, till at last being wholly decomposed it leaves the lime again in the state of carbonate, ready to begin anew the same round of change."

Lime then acts an important part in the preparation of food for the plant, and is ever producing changes in the soil, if vegetable matter be present, that are productive of good results. Upon light sandy soils, the application of lime unaccompanied by vegetable manures, would be worse than useless; its mechanlcal effect would be to make more loose and porous a soil already too permeable, or, by combination with the sand, to form hard, lumpy masses unfavorable to vegetation and resisting the different pulverizing agencies, both natural and mechanical. A proper admixture of lime however, either caustic or in the form of a carbonate, with the different forms of vegetable manure, will enrich most soils, giving them a productiveness of which they seemed before incapable.

The action of lime is not limited to the production of the changes just described; it is instrumental also in producing ammonia for the plant, as has been before intimated. The following experiment somewhat similar to one given in another place, will indicate its action in this respect. Quicklime and clay intermixed and moistened, will evolve ammonia; this gas seems to be confined by the clay, but the action of lime releases it. Ammonia is also evolved by the decomposition by means of lime of those vegetable substances that contain nitrogen; upon this point Johnston uses the following language.

Give the effect of lime upon sandy soils when unaccompanied by vegetable matter. What other effect does lime produce? How may ammonia be released from its combination with clay.

"I have hitherto, for the sake of simplicity, directed your attention solely to the action, whether immediate or remote, which is exercised by lime upon organic matter supposed to contain no nitrogen. Its action upon compounds in which nitrogen exists is no less beautiful and simple, perhaps even more intelligible and more obviously useful to vegetation.

There are several well known facts which it is here of importance to consider:—

1. That the black vegetable matter of the soil always contains nitrogen. Even that which is most inert retains a sensible proportion of it. It exists in dry peat to the amount of about 2 per cent. of its weight, and still clings to the other elements of the organic matter, even after it has undergone those prolonged changes by which it is finally converted into coal. Since nitrogen, therefore, is so important an element in all vegetable food, and so necessary in some form or other to the healthy growth and maturity of plants, it must be of consequence to awaken this element of decaying vegetable matter, when it is lying dormant, and to cause it to assume a form in which it can enter into and become useful to our cultivated plants.

2. That if vegetable matter of any kind be heated with slacked lime, the whole of the nitrogen it may contain, in whatever state of combination it may previously exist, will be given off in the form of ammonia. The same takes place still more easily if a quantity of hydrate of potash or of hydrate of soda be mixed with the hydrate of lime. Though it has not as yet been proved by direct experiment—yet I consider it to be exceedingly probable, that what takes place quickly in our laboratories, at a comparatively high temperature,

---

What does the black vegetable matter of the soil always contain? What effect is produced by heating vegetable matter with slacked lime?

may take place more slowly also in the soils, and at the ordinary temperature of the atmosphere.

3. That when animal and vegetable substances are mixed with earth, lime, and other alkaline matters, in the so-called nitre beds, ammonia and nitric acid are both produced, a quantity of nitrogen contained in the weight of these compounds extracted being much greater than was originally present in the animal and vegetable matter employed. Under the influence of alkaline substances, therefore, *even when not in a caustic state*, the decay of animal and vegetable matter in the presence of air and moisture causes some of the nitrogen of the atmosphere to become fixed in the soil in the form of ammonia or nitric acid. What takes place on the confined area of a nitre-bed, may take place to some extent also in the wider area of a well-limed and well-manured field."

" In the action of alkalies in the nitre-bed, *disposing* to the production of nitric acid, we observe the same kind of agency, which we have already attributed to lime, in regard to the more abundant elements which exist in the vegetable matter of the soil. It greatly persuades all the elements—nitrogen and carbon alike—to unite with the oxygen of air and water, and thus ultimately to form acid compounds with which it may itself combine."

" The action of lime upon such organic matters containing nitrogen as usually exist in the soil, may therefore, be briefly stated as follows:—These substances, like all other organic matters, undergo in moist air—and therefore, in the soil—a spontaneous decomposition, the general result of which is the production of ammonia, and of an acid substance with which the ammonia may combine."

What effect is produced in nitre beds? Where is a similar effect produced? What is produced besides ammonia by the action of lime upon organic matter?

"If the ammonia happens to be produced in larger relative quantity than the acids with which it is to combine, or if the carbonic acid be the only acid with which it unites a portion of it may escape into the air. This rarely happens, however, in the soil, the absorbent properties of the earthy matters of which it consists, being in most cases sufficient to retain the ammonia, till it can be made available to the purposes of vegetable life.

When caustic (hydrate of) lime is added to a soil in which ammonia exists in this state of combination with acid matter, it seizes upon the acid and sets the ammonia free. This it does with comparative slowness, however, for it does not at once come in contact with it all —and by degrees, so as to store it up in the pores of the soil till the roots of plants can reach it, or till it can itself undergo a further change by which its nitrogen may be rendered more fixed."

"Carbonate of lime, on the other hand, still more slowly persuades the ammonia to leave the acid substance (ulmic, nitric, &c.,) with which it is combined, and yielding to it in return its own carbonic acid, enables it in the state of soluble carbonate of ammonia to become more immediately useful to vegetation."

The effect of lime upon noxious compounds.

It has been stated that the sulphate of iron is sometimes formed in the soil and injuriously effects vegetation. By the action of lime this salt is decomposed and the resulting compounds possess fertilizing qualities; sulphate of lime (gypsum) and oxide of iron are formed; the former is a well known fertilizer and the latter, by absorbing oxygen from the air becomes servicable to the plant.

With what do these acids combine? State the effect of caustic lime upon ammonia already combined with acids. What is said of carbonate of ammonia? How may the injurious effects of the sulphate of iron be prevented?

Lime exerts its decomposing action upon several other compounds, some of which are pointed out in the following remarks. "Lime decomposes also the sulphates of magnesia and alumina, both of which are occasionally found in the soil, and being very soluble salts, are liable to be taken up by the roots in such quantity as to be hurtful to the growing plants. When soils which contain the salts I have mentioned, have once been limed or marled, it is in vain to add gypsum in the hope of favoring the clover crop, since the lime, in decomposing the sulphates, has already formed an abundant supply of this compound for all the purposes of vegetation.

Potash and soda exist to some extent in clay soils in combination with their alumina. The presence of lime has a similar influence in setting the alkalies free from this state of combination also."

"In the presence of decaying organic substances, the carbonate of lime is capable of slowly decomposing common salt, producing carbonate of soda, and chloride of calcium. It exercises also a similar decomposing effect, even upon the sulphate of soda, and according to Berthollet, incrustations of carbonate of soda are observed on the surface of the soil, wherever carbonate of lime and common salt are in contact with each other. If we consider that along all our coasts common salt may be said to abound in the soil, being yearly sprinkled over it by the salt sea winds; that generally, along the same coasts, the application of sulphates produces little sensible effect upon the crops, and that, therefore, in all probability they abound in the soil, derived, it may be, from the same sea spray, we may safely conclude, I think, that the decomposition now ex-

---

What other compounds does lime decompose? In what cases is it vain to apply gypsum? What is the effect of carbonate of lime upon the alkalies potash and soda? State its effect upon common salt.

plained must take place extensively in all those parts of our island which are so situated, if lime in any of its forms either exists naturally or has been artificially added to the land. The same must be the case also in those districts where salt springs occur, and generally over the new red sandstone formation in which sea salt more especially occurs.

And if we further consider the important purposes which the carbonate of soda thus produced may serve in reference to vegetation—that it may dissolve vegetable matter and carry it into the roots—that it may form soluble silicates, and thus supply the necessary siliceous matter to the stems of the grasses and other plants, and that rising, as it naturally does, to the surface of the soil, it there, in the presence of vegetable matter, provokes to the formation of nitrates, so wholesome to vegetable life—we may regard the decomposing action of lime by which this carbonate is produced as among the most valuable of its properties to the practical farmer, wherever circumstances are favorable for its exercise."

Like potash, lime seems to destroy coarse grasses and induce the growth of those more desirable. Its application upon soils infested by worms has sometimes resulted in the destruction of these destroyers of vegetable life, although this is not a certain effect.

Stiff, clay soils are greatly benefited by the application of lime, and the effect is of a twofold nature, mechanical and chemical; such soils being generally too close and retentive of moisture, are rendered more permeable to water and air by the mechanical action of lime. The chemical action of this substance has been referred to, and the manner in which it releases ammonia pointed out.

How do these changes produce a supply of silica for the plant? What is the effect of lime upon noxious weeds, worms, &c.? What are the two different effects of lime upon clay?

The question often arises among farmers, "In what form shall we apply lime?" and some directions have already been given, but we will again state the difference of the action of the various forms of lime.

The rapid decomposition of animal or vegetable matter is best effected by quicklime or the unslacked. But when the process of decomposition has been carried on to a considerable extent, the slaked lime or even that which has become a carbonate again will effect the required changes. Caustic lime may be applied profitably to clover that is to be ploughed in as manure, and also to compost heaps that contain large quantities of undecomposed matter.

No fertilizer is so generally beneficial, when applied to soils, as the one under consideration, and the facilities for obtaining it are such as to place it within the reach of most agriculturists. But some caution is necessary in the application of caustic lime, or it will produce unfavorable results. It must have something to act upon, and therefore decomposable matter should be contained in the soil, or should be applied in connection with the lime. New soils, which contain an abundance of vegetable matter, should receive a bountiful supply of lime; indeed, in this way only can certain new soils be rendered fertile: and if the soil contains too much water, it always hinders, and sometimes prevents the required action of this fertilizer.

It is sometimes asserted by agriculturists, that lime rapidly exhausts the soil. This is doubtless true, and the reason is apparent. Whenever a heavy crop is obtained from a piece of land, a large amount of matter is extracted from the earth, and therefore a great yield

---

When should caustic lime be applied, and when the carbonate? What caution is given? What is said of new soils? If the soil contain too much water what will be the result? What is asserted by agriculturalists? Must not a good crop necessarily impoverish the soil to some extent.

necessarily exhausts the soil; consequently, if lime, by rendering animal and vegetable matter soluble, and fitting it to become food for the plant, produces a large crop, it must be the indirect cause of exhaustion. This, however, can be no argument against the use of lime, since, without it, we should often be unable to avail ourselves of the matter in the soil. It is certainly advisable to deprive a soil of its different fertilizing substances by means of one good crop, rather than by two poor ones, and the immediate effect of cropping, in every case, is to exhaust the soil more or less. It is a necessary consequence then, that every large crop tends to wear out the land upon which it grows more rapidly than a light one can do, whatever fertilizers may be used.

The action of lime in the compost heap, is more or less important, according to the materials contained.— When common salt is one of the ingredients its decomposition is effected by the lime, the chlorine of the salt uniting with the calcium of the lime and forming the chloride of calcium, leaves soda in its caustic state, to act upon the vegetable and animal matter contained.— Soda quickly renders the decomposable matter soluble, and fits it for becoming food for the plant. Wood ashes contain the carbonate of potash in considerable quantity, and when they form a part of the compost, lime decomposes this compound, and leaves the potash in its caustic state, and the process of decomposition is hastened by the action of this alkali.

Would it be more economical to exhaust the soil by one heavy crop than by a series of light ones? What is the effect of lime upon common salt in the compost heap? What the effect upon carbonate of potash in wood ashes? What effect do caustic soda and potash produce?