Kansas State Agricultural College.

EXPERIMENT STATION.—Bulletin 169.

ED. H. WEBSTER, *Director*.

FARM BULLETIN.

Department of Chemistry.

J. T. WILLARD, *Chemist in Charge.*

Fertilizers and Their Use.

BY

J. T. WILLARD, *Chemist.*
C. O. SWANSON, *Assistant Chemist.*
R. C. WILEY, *Assistant Chemist.*

MANHATTAN, KAN.
SEPTEMBER 19, 1910.
3166

Department of Chemistry.

J. T. WILLARD.......... Chemist in Charge.
C. O. SWANSON.......... First Assistant in Chemical Investigations.
J. W. CALVIN............ Assistant in Animal Nutrition.
R. C. WILEY.............. Assistant in Feed and Fertilizer Control.
H. C. McLEAN............ Assistant in Soil Analysis.

Work of the Department of Chemistry.

A large part of the work of the Department of Chemistry in the Experiment Station is in cooperation with other departments, by contributing the chemist's point of view in planning experiments, and in making the chemical analyses incident to investigations. Among these investigations are: Feeding experiments, conducted by the Department of Dairy Husbandry; experiments touching soil fertility, in charge of the Department of Agronomy; experiments in the study and improvement of wheat and alfalfa, by the Departments of Agronomy and of Botany, and experiments bearing upon the methods of handling and storing wheat, conducted by the Department of Milling Industry.

Among the lines of work more completely in charge of the Department of Chemistry are certain experiments touching the composition, digestibility and nutritive value of feeds; milling tests of wheat, and baking tests of flour; the collection and analysis of samples of soils, typical of the various regions of the state; the inspection and analysis of fertilizers sold in the state and the inspection and analysis of feeding stuffs sold in the state.

Bulletins are issued from time to time as required, or as the results of investigations warrant. These may be obtained without charge by addressing the Director of the Experiment Station, Manhattan, Kan.

Fertilizers and Their Use.

BY
J. T. WILLARD, *Chemist.*
C. O. SWANSON, *Assistant Chemist.*
R. C. WILEY, Assistant Chemist.

The use of commercial fertilizers in Kansas has not yet attained any extended volume. Under the provisions of an act of the legislature passed in 1907, and printed in full in bulletin No. 148, the Experiment Station is charged with certain duties in connection with the sale of fertilizers. It is unlawful within the state of Kansas to sell, offer for sale or possess for sale any commercial fertilizer which has not been officially registered by the Director of the Experiment Station of the Kansas State Agricultural College, and previous to registration the manufacturer or seller of any brand of commercial fertilizer is required to submit a statement of its guaranteed composition. If this is satisfactory to the said Director, he registers the fertilizer upon the payment of a registration fee of twenty-five dollars by the manufacturer or seller. This payment is once for all, and the law forbids changing the guaranteed composition of any brand of fertilizer after it is registered. This is to protect consumers in the use of a given brand which, if changes were permitted, might be found quite unsatisfactory at later dates. Hence, if a manufacturer desires to make a change in his fertilizer he must give it a new brand and register it under the new name.

The law also provides that the Experiment Station chemist and his deputies shall make inspection of fertilizers sold or offered for sale in the state of Kansas, and shall procure Samples of the different brands registered for sale in the state, that they may be analyzed for comparison with the guaranty of the manufacturer. These samples are obtained from lots actually on sale and are not specially prepared and furnished by the manufacturer.

TABLE I. Composition of inspection samples of fertilizers compared with the guaranties of manufacturers.

	Brand of Fertilizer.	Manufacturer.	Minimum percentage of total nitrogen.		Minimum percentage of phosphorus in phosphates. Soluble in water.		Reverted.		Insoluble.		Total.		Minimum percentage of potassium in compounds soluble in water.		Maximum percentage of chlorine in compounds soluble in water.	
			Found....	Guaranteed....	Found....	Guaranteed....	Found....	Guaranteed....	Found....	Guaranteed....	Found....	Guaranteed....	Found....	Guaranteed....	Found....	Guaranteed....
1	Lawn & Garden	Armour Packing Co	2.79	2.88	......	......	......	......	0.39	......	4.55	3.49	3.03	3.32	......	......
2	Special Grain	Swift & Co.	1.26	1.65	2.71	2.49	......	......	.16	0.88	4.47	5.25	1.44	1.66	0.60	1.51
3	Helmet Brand 2-8-2	Armour Packing Co	1.57	1.64	......	......	......	......	.16	......	4.62	3.49	1.56	1.66	......	1.65
4	Fine Ground Beef Bone	Armour Packing Co	2.92	2.46	......	......	......	......	7.56	7.85	11.22	10.47	......	......	......	......
5	Onion, Potato & Tobacco	Swift & Co.	1.61	1.65	1.95	2.18	......	......	1.10	1.31	4.49	4.80	5.16	5.82	.90	......
6	Pure Bone Meal	Swift & Co.	2.79	2.50	......	......	......	......	6.57	6.00	11.49	10.92	......	......	......	......
7	Enterprise Brand	Hull & Dillon Co.	6.81	6.74	......	......	......	......	1.59	1.07	4.37	4.02	.24	.44	2.00	......
8	Raw Bone Meal	Armour Packing Co	4.02	3.70	......	......	......	......	7.52	8.29	10.31	10.47	......	......	......	......
9	Special Potato	Armour Packing Co	1.53	1.64	......	......	......	......	.35	......	4.38	3.49	8.84	8.30	6.50	......
10	Fine Ground Beef Bone	Armour Packing Co	3.33	2.46	......	......	......	......	7.51	7.85	11.09	10.47	......	......	......	......
11	Lawn & Garden	Armour Packing Co	2.72	2.88	......	......	......	......	.45	......	3.94	3.49	3.78	3.32	4.50	......
12	Special Potato	Armour Packing Co	2.72	1.64	......	......	3.81	3.49	.71	......	4.52	3.49	4.95	8.30	.13	......
14	Ammoniated Dissolved Bone & Potash	Armour Packing Co	1.67	1.64	......	......	4.45	4.36	.46	......	4.91	4.36	1.68	1.66	2.10	1.65
15	Lawn & Garden	Armour Packing Co	2.98	2.87	......	......	4.08	3.49	1.57	......	5.65	3.49	3.14	3 32	.30	......
16	Lawn & Garden	Armour Packing Co	2.86	2.87	......	......	4.25	3.49	.43	......	4.68	3.49	3.14	3.32	.28	......
18	Special Potato	Armour Packing Co	1 76	1.64	......	......	4.87	3.49	.19	......	5.06	3.49	7.52	8.30	.48	......
19	Lawn & Garden	Armour Packing Co	2.60	2.87	......	......	4.75	3.49	.41	......	5.16	3.49	3.24	3.32	.33	......
20	Fine Ground Beef Bone	Armour Packing Co	2.70	2.46	......	......	5.38	2.61	5.18	7.85	10.56	10.48	......	......	......	......
21	Raw Bone Meal	Armour Packing Co	3.95	3.07	......	......	4.31	2.18	6.15	8.29	10.46	10.47	......	......	......	......
22	Helmet Brand 2-8-2	Armour Packing Co	1.63	1.64	......	......	4.54	3.49	.19	......	4.73	3.49	1.84	1.66	2.20	1.65
23	Helmet Brand 2-8-2	Armour Packing Co	1.95	1.64	......	......	3.86	3.49	.45	......	4.31	3.49	1.68	1.66	2.00	1.65
24	Lawn & Garden	Armour Packing Co	2.88	2.87	......	......	4.29	3.49	.45	......	4.74	3.49	3.13	3.32	.30	......
25	Helmet Brand 2-8-2	Armour Packing Co	1.61	1.64	......	......	3.69	3.49	.78	......	4.47	3.49	1.52	1.66	1.90	1.65
26	Ammoniated Dissolved Bone & Potash	Armour Packing Co	1.63	1.64	......	......	4.67	4.36	.88	......	5.55	4.36	1.45	1.66	1.85	1.65
28	Superphosphate	Swift & Co	1.54	1.65	......	......	3.76	3.49	1.46	1.75	5.22	5.24	1.45	5.24	1.70	1.66
29	Pure Raw Bone Meal	Swift & Co.	4.00	3.75	......	......	......	......	......	......	......	10 04	......	......	......	......
30	Pure Special Bone Meal	Swift & Co.	1.52	......	......	......	......	......	......	......	12.09	......	......	......	......	......
31	Special Grain	Swift & Co.	1.99	1.65	2.85	3.49	4.72	4.37	.37	.88	5.09	5 25	1.55	1.66	1.70	1.51
32	Pure Bone Meal	Swift & Co.	2.15	2.50	......	......	7.08	4.92	4.02	6.00	11.10	10.04	......	......	......	......
33	Vegetable Grower	Swift & Co.	4.50	3.29	.76	2.36	4.29	3.93	1.61	.87	5.90	4.80	8.53	8.31	1.20	......

34	Pure Bone Meal	Swift & Co.	3.49	2.50	......	......	8.01	4.92	4 50	6.00	12.51	10.92	......	......	......	......
35	Special Grain	Swift & Co.	2.52	1.65	1.24	3.49	3.69	4.37	1.93	.88	5.62	5.25	1.98	1.66	2.10	1.51
36	Special Potato	Armour Packing Co.	2.38	1.64	......	......	3.51	3.49	.49	......	4.00	3.49	8.08	8.30	1.10	......
37	Ammoniated Dissolved Bone & Potash	Armour Packing Co.	1.84	1.64	......	......	4.87	4.36	.13	......	5.00	4.36	1.95	1.66	2.00	1.65
38	Lawn & Garden	Armour Packing Co.	3.32	2.87	......	......	4.14	3.49	.11	......	4.25	3.49	3.12	3.32	2.10	......
39	Fine Ground Beef Bone	Armour Packing Co.	3.25	2.47	......	......	6.18	2.62	4.17	7.87	10 35	10.48	......	......	......	......
40	Vegetable Grower	Swift & Co.	3.30	3.29	2.12	2.36	4.53	1.57	.54	.87	5.07	4.80	9.52	8.31	.30	......
41	Fine Ground Beef Bone	Armour Packing Co.	2.48	2.47	......	......	4.39	2.62	6.35	7.86	10.74	10.48	......	......	......	......
42	Helmet Brand, 2-8-2	Armour Packing Co.	1.80	1.64	......	......	3.62	3.49	1.49	......	5.11	3.49	1.78	1.66	1.80	1.65
43	Pure Raw Bone Meal	Swift & Co.	4.25	3.75	......	......	......	......	......	......	9.75	10.04	......	......	......	......
44	Special Grain	Swift & Co.	2.19	1.65	3.59	3.49	4.84	4.37	.16	.88	5.00	5.25	1.81	1.66	1.50	1.51
45	Superphosphate	Swift & Co.	2.26	1.65	2.49	2.18	4.72	3.49	1.46	.87	6.18	4.37	1.85	1.66	1.50	1.51
46	Pure Bone Meal	Swift & Co.	2.12	2.50	......	......	4.73	4.92	5.50	6.00	10 23	10.92	......	......	......	......
47	Pure Special Bone Meal	Swift & Co.	1.35	......	......	......	......	......	......	......	10.40	......	......	......	......	......
48	Raw Bone Meal	Armour Packing Co.	4.55	3.70	......	......	2.98	2.18	6.96	8.29	9.94	10.48	......	......	......	......
50	Kaw Grain Grower	American Reduction and Fertilizer Co.	2.18	1.65	1.30	2.00	3.70	3.50	.46	.85	4.16	4.35	2.65	1.66	.50	2.00
51	Kaw Special	American Reduction and Fertilizer Co.	1.55	2.00	1.57	1.50	3.41	.70	1.45	1.80	4.86	4.00	5.10	4.00	1.00	2.50
52	Kaw Special Potash Mixture	American Reduction and Fertilizer Co.	.87	.41	1.73	1.00	2.84	1.75	.30	.42	3.15	2.17	4.45	5.00	.70	2.50

The expense of inspection and analysis is met by means of the registration fees, and an inspection tax of twenty-five cents per ton collected by means of tags which are to be attached to the packages of fertilizer or delivered with bulk lots. These tags must be obtained from the Director of the Experiment Station.

The law went into effect September 30, 1907, and this bulletin in the accompanying tables gives the results of analyses of the samples of fertilizers taken up to June 30, 1909. Comparatively few brands of fertilizers have been registered, and in some cases these have not been found in the market, although the entire state has been fairly well covered in the inspection. In some cases small quantities of fertilizers had been in stock, but none remained at the time of the inspector's visit. The observations of the inspectors would indicate that comparatively small amounts of commercial fertilizers are sold in this state.

The results of the analyses of the inspection samples of fertilizers collected show that usually the amount found is up to that guaranteed, or at least within the limit of one-fifteenth deficiency tolerated by law. In a few instances, however, there is a considerable deficiency, indicating a possible blunder in compounding the particular lot of fertilizer sampled. Comparatively few brands of fertilizers are registered in this state, and their manufacturers are evidently disposed, on the whole, to maintain the quality of their goods as placed upon the market.

TERMS RELATING TO FERTILIZERS.

Some explanation of the terms used in connection with fertilizers seems advisable at this point, especially as the science of chemistry and its specific terms cannot be assumed to be understood by the average farmer and yet are indispensable in discussing or comparing fertilizers and soils, as well as many other classes of substances with which agriculture is concerned.

When one consults the bulletins upon soils or fertilizers issued by most experiment stations he finds the expressions "potash," "phosphoric acid," "nitrogen," "lime," "ammonia" and others in common use. In the tables presented in this bulletin, while these terms may be employed at times in stating the composition of fertilizers, the significant constituents will be expressed as quantities or percentages of some chemical element. That the reader may understand the relation between this mode of expression and the older one which is in more general use, and may have a basis for understanding the limitation and value of each as a mode of indicating the usefulness of a fertilizer, an attempt will be made in the following paragraphs to present the matter in an elementary way in the hope that even those who have had no opportunity to study chemistry may grasp the essential ideas.

When the chemist investigates the various substances of which the air, earth, rocks, water, plants, animals, etc., consist, he finds that most of these are compound in character; that is, by suitable chemical treatment he can decompose them into other substances. If this process of decomposition be continued to a sufficient extent he finally may obtain substances which are incapable of further decomposition by him. These simple, undecomposable substances are the chemical elements. Many of these are well known, such as iron, copper, gold, silver, lead, tin, zinc and sulphur. Oxygen and nitrogen are elements which make up nearly the entire bulk of the air. Hydrogen is an element of which water contains 11 per cent, the remainder being oxygen.

Phosphorus is an element that is not frequently seen in common life and does not occur as such naturally. It is, however, readily prepared by the chemist. Carbon is the element which is most typical of the substances of which plants and animals consist, and when these are strongly heated without free access of air a residue of carbon with small amounts of mineral substances is left as a soft black substance known as charcoal. The hydrogen and nitrogen, and a portion of the carbon and other elements, will have been expelled in the form of volatile substances. The element carbon not only occurs in the form of charcoal but also in the diamond, and in graphite, the material used in the preparation of lead pencils.

Sodium, potassium and calcium are important metals, which are, however, never found in the uncombined state naturally, but can be separated from the compounds in which they occur by suitable chemical processes. Chlorine is a gas which also is found in nature only in combination. It is one of the constituents of common salt, the metal sodium being the other constituent.

It will be seen that most of the substances named above as elements do not occur as such in nature. As we study chemistry we find that there is a considerable tendency for elements to combine in pairs; for example, common salt consists of sodium and chlorine, water of hydrogen and oxygen, lime of calcium and oxygen, sulphur trioxide of sulphur and oxygen, phosphorus pentoxide of phosphorus and oxygen. In fact, there is a large class of compounds known as oxides each member of which consists of oxygen combined with another element. Furthermore, it has been found that many compounds are of such composition that they may be regarded as formed by the union of two oxides; thus water, a compound of oxygen and hydrogen, will combine with sulphur trioxide, a compound of oxygen and sulphur, to form sulphuric acid, which therefore contains hydrogen, sulphur and oxygen. Chemists have adopted certain symbols to represent in some sense the chemical elements. These symbols suggest not only the name of the element but they have a quantitative meaning — that is, they indicate the relative weights of the substances in a compound. The symbol H, for example, indicates hydrogen; O, oxygen; S, sulphur; P, phosphorus, but the relative weights implied by these symbols are 1, 16, 12, 32 and 31, respectively. It has been found that if certain relative weights are thus assumed to be represented by the symbols of the elements comparatively simple expressions known as formulas can be used to designate their composition. This may be illustrated to a certain extent with the hope of giving the reader some idea concerning the meaning of chemical formulas without expecting him to completely understand the reasons for them. The relative weights assumed to be signified by these chemical symbols are known in chemistry as the atomic weights, and are believed to have a fundamental connection with the actual structure of matter. It has been found, however, that chemical compounds cannot all be accounted for by assuming that, in the combination of elements to form compounds, the quantities entering into the combination are always in the same relation as the so-called atomic weights. It is, however, always possible to represent the compound by assuming that the elements enter into it in relatively simple multiples of the atomic weights. These ideas may be illustrated by means of a few examples. The combining weights, or atomic weights, of all of the elements with which we shall be concerned in this bulletin are, in round numbers :

Hydrogen, H, 1.	Potassium, K, 39.	Sulphur, S, 32.
Oxygen, 0, 16.	Calcium, Ca, 40.	Phosphorus, P, 31.
Nitrogen, N, 14.	Magnesium, Mg, 24.	Chlorine, Cl, 35.5.
Sodium, Na, 23.	Carbon, C, 12.	

In using these symbols and atomic weights to indicate substances produced by the combination of these elements we write the symbols of the elements entering into the compound side by side, and if more than one atomic weight of any element is to be represented a small figure is placed to the right and somewhat below the symbol. There is, for example, a compound of potassium and chlorine known as potassium chloride. If this compound be carefully analyzed it is found to contain the metal potassium and the nonmetal chlorine in the ratio of 39 to 35.5. We may therefore adopt the formula KC1 as representing potassium chloride, not only as showing the chemical elements of which it consists but also their relative amounts, since "K" is always to be understood as representing a relative quantity of 39 and "Cl" one of 35.5. The metal calcium also forms a compound with the nonmetal chlorine. Chemical analysis shows that in this the relative amounts of calcium and chlorine are 40 and 71; that is, we have with, one combining or atomic weight of calcium two atomic weights, 2 x 35.5, of chlorine. We can represent this compound both as to the kinds of elements of which it consists and their relative amounts by the formula $CaCl_2$, in which Ca indicates a relative weight of 40 and Cl a relative weight of 35.5, and the $_2$ shows that this last is taken twice. This mode of indicating the quantitative composition of compounds may seem at first to be roundabout and cumbrous. It is, however, in the direction of simplicity, as relatively simple formulas indicate compounds the composition of which could not be represented simply by percentages. And, moreover, by this system very simple relations are found to exist among the different classes of compounds. Thus it will be seen that there is a simple relation between potassium chloride, KCl, and calcium chloride, $CaCl_2$. In the latter there are two combining weights of chlorine for one combining weight of the calcium, while in the former there is one combining weight of the chlorine for one of the potassium. If we should express these compounds in percentages we would have in the potassium chloride 52.3 per cent of potassium and 47.7 per cent of chlorine, and in the calcium chloride 36 per cent of calcium and 64 per cent of chlorine, figures which do not give any hint of the simple relation existing between the two compounds in respect to the amount of chlorine. Throughout the whole realm of chemistry the representation of chemical compounds and their relations among each other is brought out only when the symbols of the elements are at the same time taken to indicate a definite quantitative composition represented by the atomic weights taken one or more times as the formula may indicate.

As indicated above, it was early noticed that elements tended to combine in pairs and that the compounds so produced might combine with other compounds. We may illustrate this further. Calcium and oxygen combine in the ratio of 40 of calcium to 16 of oxygen to form the common compound lime—that is, quicklime. As the numbers in this ratio are the same as those given above for the combining weights the formula of the compound is CaO. This formula represents that calcium and oxygen are combined in the ratio of 40 to 16 by weight just as definitely as if the fact were stated. Sulphur and oxygen form the compound sulphur trioxide, the relative amounts of sulphur and oxygen being 32 and 48, respectively. The combining weight of sulphur being 32, and of oxygen 16, one-third of 48, we must represent sulphur trioxide by the formula SO_3 Lime and sulphur trioxide will combine together to form the compound calcium sulphate. In this the relative amounts of calcium, sulphur and oxygen are 40, 32 and 64, respectively, and hence it may be represented by the formula $CaSO_4$. This formula it will be seen is equal to CaO and SO_3 added together. In an earlier stage of chemical science this was written CaO,SO_3. This emphasized the idea held at that time that chemical compounds in general are formed by the union of two things. In this case the two were CaO, lime, and SO_3, sulphur trioxide, or, as it was then called, sulphuric acid.

Let us take another example. Phosphorus and oxygen combine to form phosphorus pentoxide. In this the ratio of phosphorus to oxygen is as 62 is to 80. As the atomic weights of phosphorus and oxygen are 31 and 16, respectively, the formula of phosphorus pentoxide is found by dividing 62 by 31, and 80 by 16, and is thus P_2O_5. This substance in the early part of the last century was called phosphoric acid. Calcium oxide, or lime, and phosphorus pentoxide, or "phosphoric acid," are capable of uniting together to form the compound calcium phosphate, in which the relative amounts of calcium, phosphorus and oxygen are 120, 62, and 128, respectively. If these numbers be divided by the atomic weights of those elements we obtain, as the formula for calcium phosphate, $Ca_3P_2O_8$. It will be seen that in composition this is equivalent to three of calcium oxide plus one of phosphorus pentoxide, and this relation may be brought out by writing the formula $3CaO,P_2O_5$; that is, the compound may be said to consist of "lime" and "phosphoric acid," to use the old terms, or calcium oxide and phosphorus pentoxide, if the modern names be used, Without going into details, it may be stated that by this old system potassium phosphate would be represented as $3K_2O,P_2O_5$. The name "potash" was given to the potassium oxide, K_2O, but unfortunately the term is also applied to other compounds. Common saltpeter contains potassium, nitrogen and oxygen, and the relative amounts of these elements are 39,14 and 48, respectively, numbers corresponding to the atomic weights, excepting that in the case of oxygen it is three times as great. We therefore give the substance the formula KNO_2. If this be multiplied by 2, making $K_2N_2O_6$, it will be seen to be equivalent to K_2O, N_2O_5. In the early days previously referred to, N_2O_5 was known as nitric acid, and this substance was said to consist of "potash" and "nitric acid." In a similar way Chili saltpeter, now represented by the formula $NaNO_3$, was given the formula NaO, N_2O_5, and calcium nitrate, the old name for which was nitrate of lime, now given the formula CaN_2O_6, or $Ca(NO_3)_2$, was represented as CaO,N_2O_5.

By studying the old formulas as given above it will be seen that each of them is twofold in its nature and represents an oxide of a metal and an oxide of a nonmetal, and that these oxides occur in the different substances; thus CaO, "lime," is represented as present in the calcium sulphate and calcium phosphate and calcium nitrate; the "phosphoric acid," P_2O_5, was represented as present in potassium phosphate as well as calcium phosphate and others; "potash," K_2O, was in potassium phosphate, potassium nitrate, etc.; nitric acid, N_2O_5 is present in calcium nitrate, potassium nitrate and sodium nitrate. It will be seen that this binary system possesses some obvious advantages and that it is possible to speak of a series of substances as containing "lime," another series as containing "phosphoric acid," another "potash," another "sulphuric acid," etc. This system of thought and method of stating results was used so much in connection with the analysis of soils, rocks and fertilizers during the last century that a large mass of material was accumulated in which the results of the analyses are expressed in these old terms.

However, with the progress of chemical science the views concerning the nature of chemical compounds have changed radically, and many of the names used above are no longer used in that sense in the systematic science of chemistry. The young student of to-day studies an entirely different substance than P_2O_5 under the name of "phosphoric acid"; "sulphuric acid" in modern language is not SO_3; "nitric acid" is not N_2O_5; "potash" is not K_2O; and hence the students of chemistry in our high schools and colleges to-day require special instruction in order to enable them to understand the antiquated expressions used in describing the composition of soils and fertilizers. It seemed to those concerned in drafting the fertilizer law for the state of Kansas that the only proper thing was to apply to fertilizers the system of naming used throughout 'the science of chemistry in almost every relation; that it should be placed abreast of the times and not start with a system of naming that has long been out of date and presents many complications and inconsistencies not yet brought out here. Hence the law specifies that the composition of fertilizers shall be stated in terms of the elements; that is, the amounts of potassium, phosphorus, nitrogen, etc., are to be stated rather than "potash," "phosphoric acid," or "ammonia." The problem is a difficult one to argue in a way intelligible to one who has not studied chemistry, but some of the embarrassments of the old system will be presented in as simple a manner as possible.

In the examples given above it is obviously possible to express the percentage of "potash", K_2O, "lime", CaO, "phosphoric acid", P_2O_5, etc., because in a sense each of those substances may be said to be present in the examples cited. There are, however, compounds used in fertilizers in which this is impossible. One of the important substances containing potassium used in fertilizers is potassium chloride, which contains potassium and chlorine only, and has the formula KCl. It is obvious that in no way can this be represented as containing K_2O, since it is free from oxygen. It cannot in any sense be said to contain "potash," K_2O, yet by the old system of stating the composition of fertilizers the analyst will report KCl as containing a certain percentage of "potash." What he really does in this case is to calculate from the results of his analysis the amount of "potash," K_2O, that would contain as much of the element potassium, K, as he finds in the fertilizer analyzed. The potassium found is equal in amount to that in the "potash" reported, and in a sense may be said to represent that amount of "potash." However, the oxygen is not there in that case, it is not the constituent which gives value to those potassium compounds which contain it, and it is far more logical to state the percentage of the particular elements in which we are interested than to calculate the amount of some other compound which may or may not be represented in the fertilizer and which is certainly not present as such any more than the potassium is present in the free and metallic state.

In the case of nitrogen, matters are in some states still worse, if possible. The nitrogen of fertilizers is present in various classes of compounds, among which are ammonium salts, nitrates, and the organic nitrogenous substances found in plants and animals. In stating the results of the analysis of a fertilizer it is the practice of some to ascertain the percentage of nitrogen and then to calculate the ammonia which if present would contain an amount of nitrogen equal to that found by the analysis. The fertilizer is then reported to contain that much "ammonia." In point of fact it not only does not contain ammonia, but in many cases it contains no compounds of ammonia, but instead nitrates and organic nitrogenous compounds. Reporting the results as "ammonia" is therefore wholly artificial, and is misleading in that the purchaser is given the wrong idea if he obtains any idea.

The question of the advisability of abandoning the old system of expressing the results of the analysis of fertilizers and soils, and substituting one in harmony with the later views that have dominated chemistry for over half a century, is one that has been discussed warmly at meetings of chemists, and thus far no unanimity of view has been attained. Those who are accustomed to the old system dislike to adjust themselves to a new one. They claim that it will be confusing to farmers. It may be conceded that farmers who have become accustomed to the old system may have difficulty in adapting themselves to a new one, but in point of fact comparatively few farmers understand the old system except that they have seen certain figures representing percentages set opposite the words "potash," "phosphoric acid" and "ammonia." The words mean nothing except as a means of identifying certain figures. If the results were reported in terms of the elements potassium, phosphorus and nitrogen the figures would be different and could not be compared directly with the results expressed by the old system. They would, however, be directly comparable with all results expressed by the modern system. It is, moreover, entirely practicable, as a transition plan, to have the composition of fertilizers expressed by both systems. This is, however, not necessary in this state, as the use of fertilizers is very limited and the intelligence of our citizens is such that they will be able to grasp promptly the relation between the antiquated system and the modern one, and will prefer the latter. As the use of fertilizers increases the education of the public concerning them will be in the same terms as those used in the education of children in the public schools and colleges, and the state will not be burdened by an excrescence in the form of a system of naming that has been out of use in scientific chemistry for half a century.

Some, in opposing the introduction of modern terms in connection with fertilizers, have argued that farmers might think that because the elements potassium and phosphorus are dangerously inflammable, and in that form would be wholly unfit to keep about a barn or apply to crops, fertilizers containing these elements should not be used. They lose sight altogether of the fact that potash and phosphoric acid, whether we use these names in the modern or the antiquated, sense, represent compounds which it would be equally as dangerous to apply to crops and almost equally as unpleasant to handle, if not as dangerous. The fact of course is that the substances actually used as fertilizers are neither potassium, phosphorus, nitrogen, phosphoric acid, potash or ammonia, but quite different substances, in which, however, their value as a fertilizer is measured by the potassium, phosphorus or nitrogen which they contain. Were it possible to do so, the best mode of stating the composition of a fertilizer would be to give the percentage of each of the compounds actually present, such as potassium citrate, potassium chloride, potassium sulphate, sodium nitrate, calcium phosphate, monocalcium phosphate, etc.

While the ideal mode of statement of the composition of a fertilizer is to state the amounts of each individual compound present, chemical analysis has not arrived at such a state of development as to enable us to analyze a fertilizer so as to tell exactly what compounds of the different elements are present. Thus, a fertilizer may contain potassium in potassium chloride, potassium sulphate, potassium carbonate, and other compounds, but it is quite impossible to so analyze it as to ascertain the amounts of potassium present in each of these classes. We can only determine the total amount of potassium, or the amount that is present in compounds soluble in water, or, possibly, in some other solvents.

The condition is similar in respect to nitrogen. The nitrogen of fertilizers now on the market may be present in the form of ammonium chloride, ammonium sulphate, potassium nitrate, sodium nitrate, calcium cyanamide, or in any one of a large number of nitrogenous organic compounds, some of animal and some of vegetable origin, and even in other compounds. It is at present far beyond the power of the chemist to analyze such a mixture and ascertain the exact proportion of each compound of nitrogen present. The best that can be done yields only partial results in this direction. Similar conditions apply to the compounds of phosphorus.

It will be seen, therefore, that it is impossible to report the composition of a fertilizer in terms that will state the amounts of each individual compound present, and the simplest method of reporting is to state the percentage of each significant element present. In the case of the nitrogenous substances, for example, while there are differences in the availability and agricultural value of them, since it is impossible to ascertain the amount of each compound, and the element nitrogen is the one found in all of them upon which the fertilizing value depends, a statement of the total amount of nitrogen would seem to be the simplest method of dealing with the question. In addition to this, however, it is possible with reference to some classes of compounds to investigate the matter somewhat more closely and learn something concerning the nature and amount of the individual compound or classes of compounds present. This is possible, and especially advantageous, in so far as we may determine the nitrogen, potassium, etc., present in compounds soluble in water and the amounts present in compounds insoluble in water. The soluble compounds are immediately available to plants, while the insoluble ones may require long and slow chemical processes to take place before plants can avail themselves of the needed elements. In addition to pure water other reagents are used in getting more detailed information concerning the character of the constituents of a fertilizer than is afforded by merely ascertaining the total amount of a given element present.

The value of potassium compounds not soluble in water is so slight that fertilizer laws uniformly take into account as valuable only those compounds which are soluble in water.

In the case of nitrogen the total amount of the element is usually ascertained, and when practicable the amount of this present as nitrates and ammonium salts, respectively, is also reported. The nitrogenous organic substances are so various in nature and of such diverse properties that as yet no mode of analysis has been agreed upon by which we may obtain a measure of the agricultural value of such nitrogenous substances. Some are no doubt practically equal to nitrates and ammonium salts, while others are so inert, so resistant to fermentation and other chemical change, that many of the states prohibit their introduction into fertilizers. Horns, hoofs, hair and feathers are examples of these inert substances. No analytical process has received general acceptance as affording a means of distinguishing accurately between the valuable organic nitrogenous substances and those that are worthless or nearly so.

In the analysis of fertilizers an attempt is made to ascertain the amount of phosphorus present in the different classes of phosphates, but this cannot be done with great exactness. fertilizer manufacturers are required to give a guaranty in respect to the phosphorus present in: (1) phosphates soluble in water, (2) reverted phosphates, (3) insoluble phosphates, and (4) the total phosphorus, which would be the sum of the other three. Reverted phosphates are soluble in a solution of ammonium citrate, and are sometimes referred to as "citrate-soluble phosphates.'' Ammonium citrate to a certain extent exerts a solvent power upon the reverted phosphate comparable with that exhibited by the roots of plants, and such phosphates are less valuable than those soluble in water. In considering the value of the phosphorus of a fertilizer, then, it is important to notice in what form of combination it is present,

MATERIALS USED IN FERTILIZERS.

Of the mineral elements required by plants only four are likely to be deficient in soils, namely, potassium, calcium, nitrogen and phosphorus, and the raw materials used in the manufacture of fertilizers are those which can be obtained on a commercial scale and contain one or more of these elements in a relatively high percentage. The commercial sources will not be treated at great length here, but on account of their general interest will be referred to briefly.

Potassium.

When plants are burned the residue left is known as the ash. If these plants are terrestrial the ash will contain a notable percentage of potassium ; on the other hand, plants that have grown in the sea, though containing important amounts of potassium, also contain large amounts of the similar metal, sodium. For many years hardwood ashes were the chief source of potassium for fertilizers. The ashes of soft wood are much poorer in this element. No doubt the character of the forest growth of a region is determined largely by the quality of the soil, and hard woods grow only on soil rich in mineral substances, while the soft woods grow on poorer types. While hardwood ashes are still sought and applied, the chief supply of potassium compounds for fertilizers is a remarkable deposit of salts discovered in Germany about the middle of the last century. These deposits have been discovered in various parts of Germany, but the most important works are in the vicinity of Stassfurt, a small city about 100 miles southwest of Berlin. This wonderful deposit was discovered in a search for common rock salt, and the potassium compounds were at first regarded as of no value; but with the progress of agricultural chemistry they have become recognized as one of the most important of all the known resources of the world, and enormous amounts of potassium compounds are exported from Germany annually.

In the Stassfurt deposits the potassium is found in several different compounds. Among these are *sylvite,* KCl; *carnallite,* $KMgCl_3.6H_2O$; and *kainite,* $K_2SO_4.MgSO_4.MgCl_2.6H_2O$. Carnallite is the most important of these salts, but on account of its small percentage of potassium is not shipped in that form to distances remote from the mines. It is submitted to treatment whereby *potassium chloride* or *"muriate of potash"* in several grades of purity is obtained, and in this form is applied as a fertilizer. Kainite is used as a fertilizer, and is exported in large quantities. *Potassium sulphate,* or *"sulphate of potash,"* is manufactured from kainite and potassium chloride. This compound is not prepared in as large quantities as is potassium chloride, but for certain crops it is preferable. To a limited extent this compound occurs ready formed in the Stassfurt deposits.

Hardwood ashes are of little commercial consequence in this state, but when available should be recognized as valuable sources of fertility, especially of potassium. They contain, of course, the other ash constituents present in the original wood, excepting certain losses that take place in the combustion, and such as may have occurred by subsequent leaching, and hence contain valuable amounts of phosphorus. The nitrogen of the wood is mostly lost in the burning. In this connection it may be mentioned that coal ashes are of practically no chemical value, but may upon some soils be of use as improvers of the physical state.

For ordinary field crops the form of combination in which the potassium is employed does not matter much, the value depending upon the percentage of potassium present. It has been found, however, that with tobacco, potatoes and sugar beets the application of fertilizers containing chlorine is quite objectionable. Hence for these crops potassium sulphate should be used rather than potassium chloride (muriate of potash). Kainite, though containing its potassium as sulphate, carries large amounts of common salt (sodium chloride) as an impurity, and hence should not be used where chlorides are prejudicial.

Phosphorus.

Phosphorus is found in various classes of compounds, the most important of which as sources of fertilizers are: *Bones, rock phosphate, apatite,* and *basic slag* from certain iron furnaces. In bones and rock phosphate the phosphorus is present as a constituent of tricalcium phosphate, $Ca_3(PO_4)_2$. Apatite is closely related to this chemically, but contains fluorine and chlorine also. In basic slag a different combination is exhibited, known as tetracalcium phosphate, and to which the formula $Ca_4P_2O_9$ is ascribed.

The bones of animals directly or indirectly constitute an important source of phosphorus. *Raw bone* contains moisture, fat, nitrogenous substances, etc., as well as phosphates, and in this state is hardly as useful as after the fat has been removed, since this fat retards the solution of the bone substance in the soil. The nitrogenous matter is, however, of great value as a source of nitrogen.

Bones may, however, receive special treatment. The fat may be extracted by solvents, leaving a more valuable fertilizer than the original bone, or both fat and nitrogenous matter may be removed by steaming or boiling. This leaves a product richer still in phosphorus, because of the removal of the substances containing none of that element. Tankage may include such cooked bone but also includes by-products of the packing houses.

In the refining of sugar large quantities of bone black are used. This is the product obtained by heating green bone without access of air, by which the organic matter of the bone is decomposed, volatile matter expelled, and a very finely divided carbon left deposited throughout the bone tissue. This bone black, pulverized to a suitable degree, is used for decolorizing syrups and other substances. After a time it is no longer useful in this way and the spent bone black is made into superphosphate.

The rock phosphates of this country occur chiefly in Florida, South Carolina and Tennessee. The mode of occurrence, physical state and percentage of phosphorus vary greatly. They are largely consumed in the manufacture of superphosphate, but are also well suited for application to land without other treatment than grinding. This raw phosphate is less easily assimilated by plants, but as the price is much lower it has been found, in some cases at least, that an equal expenditure will produce as great an increase in crops when the ground raw phosphate is used as is obtained by employing superphosphate made from the rock. As phosphates are not much subject to leaching out from soils it will be seen that from the standpoint of total amount of soil fertility added the raw phosphate might be much more economical.

Basic slag is sold under various names. It is obtained in the Thomas-Gilchrist method for the production of iron from ores containing phosphorus. In this lime is used which, combining with the phosphorus, produces a slag rich in that element, and which when finely ground is a valuable fertilizer. It scarcely reaches our state as yet, being produced mainly in European countries.

Apatite is a mineral occurring, mixed with other rock, in considerable quantities, in Canada. It is present in minute crystals in many granite rocks and is probably the most important original source of the phosphates of soils. For use in fertilizers the Canadian apatite requires conversion into superphosphate.

The natural phosphates are only very slightly soluble and hence not easily taken up by plants. They are therefore not suitable for direct use as fertilizers where a strong, quick action is desired. They are usually rendered more soluble previous to use by being treated with sulphuric acid. The following equation expresses the result that takes place with calcium phosphate, whether it be the rock phosphate or the bone phosphate :

$$Ca,(PO,)_2 + 2H_2SO_4 = CaH_2(PO,)_2 + 2CaSO_4.$$

It will be seen that the essential change consists in the exchange of calcium, Ca, and hydrogen, H. The compound $CaH_4(PO_4)_2$ is known to chemists as monocalcium phosphate or acid calcium phosphate, other names being also in use. The $CaSO_4$ is the same as burnt gypsum. The superphosphate of commerce contains these two substances mixed, and hence not only supplies phosphorus, but calcium, the characteristic metal of lime, limestone, and gypsum or land plaster.

When a superphosphate is applied to the soil, changes are likely to set in at once by which it tends to revert to the original nearly insoluble triphosphate, $Ca_3(PO_4)_2$. There is, however, a substance intermediate in composition, known to chemists as calcium diphosphate, as well as by other names. Since it is produced in soils by a process the reverse of that by which superphosphate was manufactured, it is in agriculture often designated as *reverted phosphate.* The following equations show two of the reactions by which the acid phosphate or superphosphate may be changed in the soil to the dicalcium phosphate or reverted phosphate, by the action of calcium carbonate from limestone, or by that of the insoluble triphosphate present :

$$CaH_4 (PO,)_2 + CaCO_3 = 2CaHPO_4 + H_2O + CO_2.$$

Monocalcium phosphate.	Calcium carbonate.	Dicalcium phosphate.	Water. ,	Carbon dioxide.

$$CaH_4(PO_4)_2 + Ca_3(PO_4)_2 = 4CaHPO_4.$$

Monocalcium phosphate.	Tricalcium phosphate.	Dicalcium phosphate.

By other reactions, in some cases still more complex, compounds of iron and aluminum, present in all soils, cause the reversion of phosphates from the soluble monocalcium phosphate condition to the less soluble but still available dicalcium phosphate, and even to the still less valuable tricalcium phosphate. These less soluble phosphates are, however, by the action of carbonic acid in the soil slowly reconverted into available forms. This carbonic acid is produced in the decay of vegetable matter or humus of the soil. Other acids are also produced which contribute to the total dissolving effect upon the insoluble phosphates. Thus phosphorus in almost any form is a valuable constituent of soils and may at some time be brought into a condition in which plants may take it up even though after many years' delay. Phosphorus is one of the elements absolutely essential for plants, and the total amount present in a soil is of very great importance, and hence the total amount introduced in any fertilizer is second only in importance to the amount immediately available; that is, in the application of phosphate fertilizers the farmer naturally expects and desires immediate results, which are secured by the use of superphosphate, but at the same time if larger quantities of phosphates can be applied in other less soluble and available forms at the same expenditure, the ultimate value of the investment may be much greater, as the phosphorus will remain in the soil and be rendered available by slow natural processes.

Nitrogen.

The materials used as sources of nitrogen by the fertilizer manufacturer are quite varied. Most of these are of no immediate interest to the farmer. They may be classified in the two groups of *inorganic compounds* and *organic waste materials.*

The inorganic compounds are of three classes: *Nitrates, ammonium salts,* and *calcium cyanamide.* The organic waste most available in the West is that from packing houses, and consists of the *nitrogenous tissues* unfit for food, either from their inherent nature or because of the unwholesome condition of the animal. In the South *cottonseed meal* has been used as a fertilizer, but when in wholesome condition such use is wasteful in that the meal is a valuable feed, and when used as such the excretions of the animal contain a large proportion of the nitrogen, which may then be applied as a fertilizer, thus serving the double purpose of supporting both stock and land.

The principal nitrate used in fertilizers is *sodium nitrate* or *Chili saltpeter,* the old name for which is *nitrate of soda.* This important substance is found in large deposits of unknown origin occurring in the rainless regions of Chili and Peru. For use the crude natural substance is purified by extraction with water and recrystallization, and the commercial article is about 95 per cent pure and contains 15 to 16 per cent of nitrogen. The chemical formula is $NaNO_3$.

In the manufacture of gas by heating soft coal, considerable amounts of ammonia are produced from the nitrogenous plant residues still existing in the coal. In the purification of the gas for use in lighting, the ammonia is absorbed by the use of sulphuric acid, ammonium sulphate being produced. This is crystallized by evaporation of the solution in which it formed, and constitutes a concentrated source of nitrogen. The pure substance would contain over 21 per cent of nitrogen. Its chemical formula is $(NH_4)_2SO_4$.

Calcium cyanamide, $CaCN_2$, is a substance only recently used in fertilizing, and is made by passing nitrogen over heated calcium carbide. It seems likely to become a very important source of nitrogen for fertilizing land. Quite recently it has been found that nitrogen and hydrogen under great pressure and in the presence of osmium or uranium unite to form ammonia with such ease and rapidity that the process is exceedingly promising as a means of preparing compounds of nitrogen from the inexhaustible store of that element in the atmosphere.

Of the nitrogenous waste products of the packing houses a few may be mentioned in greater detail. Animals condemned for food purposes, and parts of others, including flesh, tendons and connective tissue, are treated to remove the fat, and then the residue is ground, and may be used in fertilizers if not suitable for cattle feed. Dried blood is similarly utilized. Hair, hoofs, horns, leather scraps, etc., contain high percentages of nitrogen and not infrequently are introduced into fertilizers. They are so slow to decay, however, that they are not in good repute for such use, though by special treatment their condition may be improved. In this state their use in commercial fertilizers is prohibited.

The fact may also be mentioned here that the organic residues of leguminous crops are an important source of nitrogen to soils, though not used in the preparation of commercial fertilizers. Nitrogen, though the element most quickly exhausted from a soil, is also the one most cheaply restored, since by the cooperation of clovers, alfalfa, peas, beans and other legumes with bacteria that grow upon their roots the abundant nitrogen of the air in the pores of the soil is brought into organic combination. This means of adding nitrogen to a soil must never be lost to view, and the purchase of nitrogenous fertilizers should be limited to the meeting of the special requirements of certain conditions or crops.

SOIL ANALYSIS WITH REFERENCE TO FERTILIZER REQUIREMENTS.

In the early history of Kansas no attention was paid to the composition of its soils except to boast of their inexhaustible fertility. The voice of the chemist has been lifted constantly, warning the people that this idea of possession of a fertility that is practically limitless is a delusion that can lead only to squandering of our natural resources, and to leaving posterity handicapped in the struggle for existence. To-day he is seeing his warnings justified. People in many localities of the eastern part of the state are making inquiry concerning chemical analysis of their soils with reference to learning what fertilizers should be applied and to what crops their soils are best adapted. A consideration of some of the aspects of this problem would seem to be timely.

The chemical composition of a soil is the most fundamental limit upon its usefulness. No matter what its depth, physical state or climatic environment, a soil that is actually deficient in one or more of the chemical elements essential to plant growth cannot be productive. Hence a thoroughgoing investigation of a soil cannot be made except it be on a chemical basis. However, the difficulties of a chemical investigation that shall lead to results that can be translated into definite statements concerning the special adaptation of a soil to a given crop, or into a prescription to meet its needs in the way of applications of fertilizers, are so great that at present they have been very incompletely surmounted.

All but a very small proportion of a soil is unavailable for the nutrition of plants and serves only for their mechanical support. The roots penetrate through to relatively great distances, both downward and sidewise, and thus the plant is anchored to a weight that enables it to stand upright. This mechanical function of a soil may be performed by material that is wholly inert in respect to nourishing the plant, or by material that to a certain extent is capable of undergoing changes whereby it becomes available. The nature of this more or less inert portion of the soil is thus of the greatest importance in respect to the endurance of its fertility. It can be readily seen that, if a chemical analysis of the total matter of a soil be made, and it be found wanting, the soil is hopelessly poor. It is, however, only with soils that consist almost entirely of quartz sand that such results would be obtained. On the other hand, the presence in a soil of adequate amounts of all the chemical elements essential to plants is no proof that the soil is fertile, since these elements may be in forms of combination such that plants cannot get them. Chemists have therefore sought for special means of analysis that will enable them to ascertain what amounts of the several elements are available to plants, rather than the total quantities of those elements.

No chemical means have yet been discovered that will test soils as a plant does. One difficulty in the way is that the different kinds of plants differ greatly in their power to acquire nutriment from a given soil. If by prolonged research a mode of investigation should be devised by means of which quantitative results could be obtained that would be proportional to the yields given by a certain crop, under otherwise favorable conditions, the results would not be completely applicable to other crops. This adds greatly to the complexity of the problem.

The nutriment that a plant gets from the soil enters it dissolved in the soil water. It might at first sight seem that simply ascertaining what amounts of the substances in a soil are soluble in water would disclose its crop-sustaining power. This is not the case, however. In the first place, if water be kept in contact with a soil until there is reason to believe that it is saturated, and it then be removed, a fresh addition of water will dissolve more from the soil, and a third amount will dissolve yet another portion. The soil may be treated indefinitely with these successive portions of water and continue to yield material which goes into solution. In the second place, it seems undeniable that the roots of plants influence the extent to which soil particles in contact with them are dissolved, by means of substances which pass from them to the soil. In this way some crops are enabled to extract more nutriment from a given soil than others can. Again, the presence of decaying organic matter, humus, in the soil, by its production of carbonic acid, increases the solvent power of the soil water, an effect that extends over years of time. For these reasons analysis of a water solution of a soil will not teach us what capacity for nourishing plants the soil possesses.

As plants have some specific solvent effect upon soils, chemists have attempted to find a solvent that will imitate their action. In this they have only partially succeeded. The use of a two-per-cent solution of citric acid, suggested by Dyer, has in many cases given consistent indications. In others the cultural experience has been at variance with what would be suggested bythe analytical results. We have not thus far any solvent that will upon all soils give results that will be consistent with the yield returned by a single kind of crop, much less by all kinds, and it is not to be expected that such a solvent will ever be discovered. The conditions of absorption of plant food by the living cells of the rootlets are different from those presented by an indifferent substance. This is indicated, not only by recent observations on osmosis, but more simply by the fact that different kinds of plants growing together in the same solution or soil take up quite different quantities of the nutritive salts. This so-called selective action must determine that each kind of plant is for itself an independent case for investigation in respect to its relations to soil fertility and soil analysis.

Whatever may ultimately be accomplished in devising means of imitating the action of plants upon soils the results so obtained will indicate the immediate capacity of the soil rather than its aggregate fertility. As previously stated, soils may have a part of the chemical elements in such stable and insoluble combination as to put it entirely outside the probably more or less remotely available plant-food supply. Aside from this nearly insoluble part we have another that dissolves in moderately strong hydrochloric acid. What will dissolve in a few days in hydrochloric acid will dissolve in weaker acids, such as are found in soils containing humus, if a few years or centuries be given, and the amounts progressively dissolved be removed by the roots of plants. The ultimate quantities of the elements of fertility that can be utilized by crops is thus taken to be practically those that may be brought into solution by hydrochloric acid of specific gravity about 1.12. A chemical analysis of such a solution may be of great value in determining the probable permanent durability of a soil, and to a less extent its immediate capacity.

It has been found that any virgin soil that shows an ample supply of nutritive substances soluble in acid as described will be fertile provided that there are no greatly opposing influences in the physical condition of the soil or in the climate. With soils long under cultivation, however, by whatever means they may be analyzed results may be obtained that are more or less contradictory to cultural experience.

Soils may get into a condition of nonproductivity, the causes of which are obscure as yet. The influence of the previous cropping, whether different or the same, may greatly affect the yield of the present season. In some cases failures are traceable to fungus diseases with which the soil becomes affected. In other cases there is reason to believe that crops leave something in the soil that hinders the growth of succeeding crops of the same kind until it is removed. Some experiments by the bureau of soils have shown that in certain cases this condition seems to be corrected by the use of substances which do not themselves contain chemical elements of fertility. It is not impossible that a part of the beneficial effect of commercial fertilizers and barnyard manure is due to such action, though there can be no doubt that their effect is not limited to this, but that they supply needs of the crop in respect to chemical elements. The need of rotation of crops in order to maintain proper soil conditions is probably greater with many soils than is its need on account of any partial exhaustion of chemical elements.

The difficulty of drawing inferences concerning crop-producing power from chemical analyses only may be illustrated by referring to an experiment by Hilgard, in which a highly productive but heavy clay soil was mixed with one, three, four and five times its weight of purified sand. Plants were grown in a pot of the original soil, and in pots of soil of the four degrees of dilution by sand. It was found that up to and including the dilution with four times its weight of sand the plants made better growth in the diluted than in the original soil. Here, then, was an example of a soil mixture with only one-fifth as much of the nutritive elements, and these in the same ratios to each other as in the original soil, that gave even better results than the undiluted soil. In short, chemical composition is very important, but it is only one of the important considerations in respect to productivity.

Not only is the physical state of the soil an important factor in determining crop yield, but its depth, and the depth, composition and general character of the subsoil are of the greatest significance. Further, in respect to sampling a soil for analysis, if this be not properly done, so that the sample analyzed actually represents the land under investigation, the results of the analysis are worthless as a basis for any general conclusion.

It will be seen from the foregoing that a chemical analysis of a single soil sample may mean very little, but to be of any service it must be considered in connection with many other things. To be of the most use it should be possible to compare it with the results of analyses of adjacent uncultivated soils and of other soils in similar climatic environment. The physical conditions must also be carefully considered.

Partial analyses of soil directed toward answering definite limited questions are often very useful. Soils have been known to contain an abundance of nitrogen and yet to be deficient in that element in an available form. Organic matter may be so slightly decomposed as not to be in a condition to furnish nitrogen to crops, while the fully humified part can undergo nitrification promptly and thus supply this element, hence a distinction in the analysis between these two forms of nitrogenous matter may contribute much information. So, too, it has been found that phosphorus in humus is more available to the wheat crop than when in some other forms of combination.

So-called alkali soils are soils containing an excess of soluble mineral substances which do not in all cases give an alkaline reaction. An analysis of a soil with reference to excessive amounts of such mineral substances may be made a useful preliminary to any treatment to improve the condition. A qualitative analysis is certainly necessary, as the nature of alkali differs greatly and proper treatment of it cannot be prescribed without knowing the nature of the excessive salts present.

Some soils are deficient in lime, or, speaking more exactly, in calcium compounds, especially the calcium carbonate which is capable of neutralizing organic acids. A fertile soil for agricultural crops must be in a neutral or faintly alkaline condition. Analyses with reference to soil acidity are therefore often of much value. Independent of acidity leguminous crops, such as clover and alfalfa, require large amounts of calcium, and regions other than those in which limestone and gypsum are found may often require special investigation in respect to the calcium content of the soil.

PHYSICAL TESTS OF SOILS.

The limitations upon the extent to which chemical analysis, can be used in forming a judgment upon soils has led to attempts to replace that mode of investigation by physical or mechanical analyses in which the size of the soil particles and in part the peculiarities of their mode of aggregation are studied. The relative dominance of certain sizes of particles in soils used largely for certain crops has been observed. However, the fact that the same crops may be quite successfully produced on soils of distinctly different mechanical composition makes this method of little practical use, however interesting a field of laboratory study it may be. The influence of rainfall, temperature, altitude, exposure and other climatic factors exceed physical constitution in their dominating position to a far greater degree than they do chemical composition. A suitable physical state may accompany an almost sterile condition. The sizes of the rock particles of a soil that has been exhausted by cropping are not materially different from what they were when the same soil was in its virgin state of fertility. At best the results of a physical examination of a soil are useless unless they are accompanied by the results of a searching chemical examination.

No kind of laboratory investigation of the physical properties of a soil possesses more than a small fraction of the value of observations upon the soil in place, with no more complicated equipment than one's eyes and hands and an auger. The lay of the land, the depth and texture of the soil and the depth and character of the subsoil are points that immeasurably exceed in importance any other physical characteristics.

INDICATIONS FROM NATURAL PLANT GROWTH.

Both chemical and physical investigation of soils in a laboratory way being limited in the usefulness of their results, these must be supplemented or in many cases replaced by observations upon the natural growth of trees, shrubs, grasses or weeds upon the soil, and by experiments in the production of plants or crops upon it. Let organic nature answer the question, What is this soil good for?

Observations concerning the natural plant growth upon a soil have always been used by practical men in judging of its value. The rich lands supporting a forest growth of oak, hickory, and other hard woods are in marked contrast with the poor, and even otherwise nearly barren, areas occupied by pines. The grasses of the rich prairies are very different in species and luxuriance from those of thin, alkaline, saline or otherwise unproductive regions. Even weeds seem to exercise a preference, and sand-bur land is very different from that best adapted to "pusley." This means of gaining an insight into soil values is one that, while used from time immemorial, is worthy of more extended study and application.

TESTS OF SOIL BY POT EXPERIMENTS.

Attempts to test soils as to their productiveness or their specific needs in the way of fertilizers have been made by means of experiments conducted in pots. The sizes of the pots used have varied from that of a capacity of a few ounces to one of several hundred pounds. Very valuable results have been obtained by this method, into the details of which space does not at present permit us to enter. It can readily be seen, however, that with climatic factors largely eliminated, and with a soil no longer in its natural state of aggregation or relation to subsoil, some of the most important features controlling crop yield are left out.

TESTING SOILS BY CROPS.

By far the best method yet devised for testing soils is by means of crops grown in the open field. Such experiments, in order to eliminate variations from season to season in rainfall and other climatic influences, should extend over a series of years to yield the best results attainable, but in a single year, if the season is not too abnormal, positive indications may be obtained. It is obvious that a soil may be deficient in but one or two of the essential chemical elements, and that in that case it would be a waste to purchase and apply fertilizers supplying elements not needed. Further, one may be disposed to apply to the soil an incomplete fertilizer, or an amendment that happens to be cheap or readily available, when in fact the soil is in need of something quite different. As a matter of economy, it is highly important that the farmer ascertain what is lacking in his soil before deciding upon the purchase of commercial fertilizers, or the kind to buy. The chemist cannot tell him with certainty what the soil needs, and no method has yet been devised that is equal to that of testing the land by means of crops that have been fractionally fertilized.

A test of this kind consists in laying off a series of plats on the soil in question, selecting an area as nearly uniform as possible, and applying different fertilizers to the several plats, leaving one or more unfertilized for comparison. The number of plats required depends upon the detail with which the test is to be made. Not less than four will suffice, and if this number is selected one plat will be left with no fertilizer, to one a potassium salt, to another a nitrogenous fertilizer, and to the other a phosphate must be applied. On comparing the crops obtained on the three fertilized plats with that given by the unfertilized one, the effect of potassium, nitrogen and phosphorus compounds separately applied will be ascertained. If it be found then that the nitrogen has increased the yield while the potassium and phosphorus have had but little if any effect, the conclusion must be that the soil is in need of nitrogen and not of the other two. If the plat receiving potassium shows an increased yield, a deficiency of that constituent of the soil will be indicated.

More comprehensive results are obtained by increasing the number of plats and including, in addition to those previously named, others to which nitrogen and potassium, nitrogen and phosphorus, phosphorus and potassium, and nitrogen, potassium and phosphorus compounds, respectively, are applied. In this case, too, it is well to add another plat, to be left without any fertilizer, making nine altogether. This arrangement will show the results of each of the three fertilizing constituents and of possible combinations of them.

There is one serious drawback to an experiment of this kind. Plat experiments which are designed to be exact duplicates have frequently been found to give considerably diverse results. For example, if in the field to be tested a series of nine plats were to be laid off and no fertilizer applied to any of them, the yields obtained from the several plats would not be the same, in all probability. This source of error can be avoided in two ways. The first is by testing the land for a few years without fertilizers, in order to ascertain the relative yields of the plats in their natural state. This is probably the best method as preliminary to a thorough investigation, but does not yield immediate results. The other method is to multiply the series of plats as many times as practicable and take the average result of the corresponding plats. Thus, if the series were repeated three times we would have the arrangement indicated by the accompanying diagram.

The average yield without fertilizers of the twenty-five plats will be shown by the average of plats 1, 9, 17 and 25, to which no fertilizer is applied, and the result will obviously be more reliable than if we should depend upon any one of these alone. Even if the total amount of land devoted to the experiment be no greater, these four plats represent the total area more truly than any four side by side do. So, too, the effect of a nitrogenous fertilizer alone will be shown with greater accuracy by taking the average yield of plats 2, 10 and 18 than would be the case by applying nitrogen to a single plat three times as large. The same considerations, of course, apply to all of the others, and the greater the number of repetitions of these series the more reliable the conclusions drawn from the results.

A PLAT FOR EXPERIMENTAL FERTILIZING.

1.	Nothing.
2.	Nitrogen.
3.	Potassium.
4.	Phosphorus.
5.	Nitrogen and potassium.
6.	Nitrogen and phosphorus.
7.	Potassium and phosphorus.
8.	Nitrogen, potassium, and phosphorus.
9.	Nothing.
10.	Nitrogen.
11.	Potassium.
12.	Phosphorus.
13.	Nitrogen and potassium.
14.	Nitrogen and phosphorus.
15.	Potassium and phosphorus.
16.	Nitrogen, potassium, and phosphorus.
17.	Nothing.
18.	Nitrogen.
19.	Potassium.
20.	Phosphorus.
21.	Nitrogen and potassium.
22.	Nitrogen and phosphorus.
23.	Potassium and phosphorus.
24.	Nitrogen, potassium, and phosphorus.
25.	Nothing.

The interpretation of results obtained from such a series of plats is easy, Representing the entire series by the numbers of the first ones, it is obvious that if no material differences are noticed in the yields of the several plats, no fertilizers would be advantageous. If Nos. 2, 5, 6 and 8 showed increased yields not exhibited by any other plats, the necessary conclusion would be that the soil is in need of nitrogen, but not of anything else. If plats 2, 3, 6 and 7 showed increased yields, while plats 5 and 8 showed still greater increases, the conclusion would be that the soil is in need of both nitrogen and potassium, either of these alone producing a beneficial effect, but fertilizers containing both producing a still better result. If at the same time the plat receiving phosphorus only, showed little or no effect, and phosphorus with nitrogen, or with potassium, or with nitrogen and potassium, showed but little or no advantage over the plats receiving nitrogen alone, potassium alone, or nitrogen and potassium, respectively, it must be decided that phosphorus is not required by the soil. By similar lines of reasoning, any possible results may be interpreted, but for the greatest accuracy in such experimentation it is necessary to perform the preliminary experiments referred to, in which the relative yields of the several plats are ascertained through a series of years without the application of any fertilizers, and giving the plats strictly uniform treatment.

While these precautions are necessary for the most concordant and satisfactory conclusions, results of value may be obtained by the four-plat test first described, and no farmer can afford to spend much money for commercial fertilizers without having ascertained, by one or another of the plans above described, the actual needs of the soil. In carrying out a fertilizer test of this kind the plats should be long and narrow, rather than square, and one-tenth of an acre and upward in area.

The practical fertilizing test may, of course, be extended to include other points such as would require applications of calcium (lime) compounds or organic matter. In many cases of soils that have become unproductive or gotten out of condition the deterioration may be traced to the diminution of the humus or organic matter in them. Before deciding that commercial fertilizers are necessary, the effect of green manuring should be ascertained. It should also never be forgotten in this connection that barnyard manure, because of its content of organic matter in a state of decay, is superior to chemical fertilizers containing equal amounts of potassium, phosphorus and nitrogen compounds.

SUMMARY CONCERNING SOIL TESTING.

The preceding considerations may be summarized briefly A thorough chemical analysis of a soil is indispensable to any comprehensive study of its condition and probable durability. Such chemical analysis may not be sufficient alone to give positive indications concerning the present productiveness of the soil, or its needs in respect to fertilizers. Chemical investiga; tion directed toward certain specific points may be of great value in respect to a given soil. Laboratory tests of a purely physical character afford little if any information that cannot be obtained better by examination of the soil in its natural condition and position. The immediate fertilizer requirements of a soil are best ascertained by means of systematic fractional fertilization of different crops.

FERTILIZER REQUIREMENTS OF DIFFERENT CROPS.

Among the questions most frequently asked of experiment stations, agronomists and agricultural chemists are those requesting information concerning the kind of fertilizers and amount to be used for corn, wheat, potatoes, etc. Answering such questions is by no means simple. It requires not only knowledge concerning the composition of the mineral substances normally present in the crop under consideration, but the chemical characteristics of the soil should be known. The difficulty of ascertaining the latter is treated elsewhere in this bulletin. It is not the present purpose to deal minutely with the question of the fertilizer needs of specific crops. Those requiring detailed information should secure one or another of the excellent books available on the subject, such as "Fertilizers," by Director Voorhees of the New Jersey Experiment Stations, or "Soils and Fertilizers," by Professor Snyder, until recently chemist of the Minnesota station.

In the use of fertilizers there are some general principles which, if understood, are of great aid in making decisions concerning their choice, and in modifying one's practice after an experimental trial.

Each plant normally has a certain life cycle to pass through leading to the perpetuation of the species by the production of seed or other organs of propagation, such as tubers, bulbs, etc. Man in his utilization of plants looks upon them in part, from a totally different point of view from that which the plant would have, if it could have any. That is, while from the viewpoint of plant physiology the continuation of the species is all-important, in the utilization of plants by the farmer their adaptation as food is the chief consideration, and reproduction is of interest only as a means of getting more food.

The part of the plant used as food may be the seed, in which case the interests of the plant species and of the farmer are identical; or it may be the vegetative portion of the plant, the part which grows and elaborates the material put into the seed. In the latter case man may so favor this vegetative function as to impair seriously the seed production. He may also by unwise choice of fertilizers defeat his purpose to obtain seed and get instead a luxuriant growth of leaves and stems.

The maturation of plants with the production of seed is accompanied by retardation and cessation of growth in other respects. This seems to be induced in part by an accumulation of insoluble matter in the tissues. For example, cereals may be grown successfully, as far as the plants are concerned, in the absence of silica, but seed is produced with difficulty, or not at all, under those conditions, notwithstanding the fact that silica is present in the seed in but very small amount while abundant in the stems of the normally grown crops. The presence of the silica in the leaves, stems, etc., of the plants seems to be necessary as a check to growth in order to initiate the reproductive processes.

Nitrogenous manures act upon plants in a special manner. Nitrogen being a nonmetal and entering into combination in soluble inorganic salts, or in organic constituents of plant tissues, it does not necessarily accumulate as an insoluble ash-constituent in the plant cells. If the element is brought to the plant as an ammonium salt it carries with it no metal to be similarly disposed of. If taken up as a nitrate it would be accompanied by some metal which would accumulate in the tissues as some mineral salt, but the accumulations of such salts would be less rapid than if the same amount of metal were taken in in the form of sulphate, phosphate, silicate, etc.

From the causes indicated above, as well as from the preeminent position occupied by nitrogen as a constituent of protein in plants, we see ample explanation for the observed fact that nitrogenous fertilizers cause a luxuriant growth of stems and leaves, but if present in excess are liable to result in little or no seed. The effects of drainage from manure piles are frequently noticeable in this way. In the case of grasses which are grown for forage and not for seed nitrogenous fertilizers are thus seen to be especially applicable. The long-continued experiments of Lawes and Gilbert, Rothamsted, England, have shown most strikingly the effect of nitrogen on grasses. Where large applications of nitrates or ammonium salts have been applied the other orders of plants have been almost completely suppressed while the true grasses have made an immense tonnage.

Though excessive use of nitrates or ammonium salts is liable to cause scanty seed-formation, a liberal amount contributes more than all other fertilizing elements to an abundant harvest of wheat, corn, oats, etc., crops which botanically are members of the great order of the grasses.

The dominant position of nitrogen in producing large wheat yields has also been most convincingly shown by Lawes and Gilbert. They made experiments, which are being continued at the present time, in which mineral fertilizers alone were applied, different quantities of nitrogen in nitrates or ammonium salts, and nitrogen compounds and mineral substances together. The accompanying table exhibits some of the results.

TABLE II. Wheat sixty years in succession on the same land (Rothamsted). Fertilizers used annually, and average yield of grain in bushels per acre, for fifty-three years, 1852 to 1904.

Plat.		Bushels.	Increase.
3-4	Unmanured	12.8	......
2B	14 tons farmyard manure since 1843	35.3	22 5
5	392 lbs. calcium superphosphate, 200 lbs. potassium sulphate, 100 lbs. sodium sulphate, 100 lbs. magnesium sulphate,	14.7	1.9
10	400 lbs. ammonium salts (86 lbs. nitrogen)	20.4	7.6
7	Same fertilizers as 5 and 10 combined	32.6	19 8
11	400 lbs. ammonium salts (86 lbs. nitrogen), 392 lbs. calcium superphosphate,	23 6	10.8
12	Same as 11, and 366 lbs. sodium sulphate	29.5	16.7
13	Same as 11, and 200 lbs. potassium sulphate	31.2	18.4
14	Same as 11, and 280 lbs. magnesium sulphate	29.7	16.9

Study of the table shows how little use it is to apply only mineral fertilizers to wheat when the soil is inadequately supplied with nitrogen. This element is stored in soils in the organic matter, and from this soluble compounds are slowly produced. Kansas farms have, in the older parts, been robbed of this organic matter and it is probable that the soil nitrogen is at present the limiting factor in grain production.

It must not be at once concluded that if nitrogen be lacking the farmer should buy nitrogenous fertilizers. The chief natural source of soil nitrogen has been the leguminous plants. For countless centuries the wild plants of this order, including peas, beans and clovers, were growing on the prairies, and with the cooperation of microscopic organisms growing on their roots accumulated the nitrogen that Kansas farmers have been exploiting. The farmer must learn a lesson from nature and repair the damage to his soil by cultivating alfalfa, clovers, etc., and seeing that the nitrogen that they accumulate gets back to the soil. Considerable amounts will be in the roots and stubble, but much more is in the leaves and stems. If these be sold from the farm in the form of hay, the land not only gets no benefit from the nitrogen contained in it, but it is further impoverished by the loss of potassium, phosphorus, calcium and other elements taken up by the plants and contained in the hay.

Permanent maintenance of fertility demands that the animal excretions produced when the farm crops are fed be returned to the land. In so far as this is not done the soil must depend on the disintegration of mineral constituents, and in many cases these are so limited in amount that the production of sterility is only a question of time.

It is a widely spread error to suppose that the production of clover or alfalfa on land is a general fertilizer for it. These crops add to the stock of nitrogenous compounds, but they diminish the stock of mineral substances.

In respect to the total amount of nitrogen required, the corn crop makes heavier demands than the wheat crop. It can, however, flourish with less available nitrogen in the soil in the spring, as its period of growth extends over a longer time and there is opportunity for the production of nitrates from the organic matter of the soil during the summer months.

The preceding paragraphs are chiefly in reference to the true grasses, including cereals. When we consider leguminous plants, such as peas, beans, alfalfa, and clovers of all kinds, the basic principles to be considered are quite different. These crops, with the assistance of the bacteria growing upon their roots, are largely independent of the soil in respect to nitrogen, and mineral fertilizers, therefore, must be chiefly considered. Calcium or lime compounds are of great importance to them. No other crop removes so large an amount of lime from the soil as does alfalfa. In soils not amply provided through limestone or gypsum with an abundance of calcium, the application of these substances to alfalfa and clover may be of vital importance. In this connection it may borne in mind that superphosphate is a calcium compound, so that when it is applied to land a double fertilizing function is performed.

For the purpose of adding calcium, slaked lime, air-slaked lime, ground gypsum or ground limestone may be used. If lime is added it will be somewhat caustic at first and may act upon organic matter and possibly mineral matter, but in a short time it will be transformed to calcium carbonate, the chief constituent of limestone.

The ash of potatoes is rich in potassium, and in fertilizing this crop this should be borne in mind and a preponderance of that element provided in the fertilizer applied. Similar fertilizing is applicable for many other garden crops. As the profit in truck gardening lies largely in the production of early and succulent vegetation, there is in this state probably no line of farming in which commercial fertilizers can be more profitably employed. As light sandy soil supplies the texture needed for the production of such crops most easily, it is also most likely to be in need of additional fertility, as such soils are liable to be deficient in soluble substances and nitrogen.

In the manuring of fruit trees and orchards it must be borne in mind that too liberal a supply of fertilizer is liable to result in the production of wood rather than fruit. For nursery stock this would be no disadvantage provided that the growth produced is not so rank as to produce soft, imperfectly matured wood. With fruiting orchards, mineral fertilizers are often of great assistance, but an excess of nitrogen should be avoided.

The New York Experiment Station (Geneva), in its Bulletin No. 94, issued a valuable compilation of information concerning fertilizers and the requirements of various crops in this respect. The practical discussion of these data adds much to its usefulness. By the courtesy of Prof. L. L. Van Slyke, author of the bulletin, we are permitted to make use of some of the material in it. The accompanying table is a rearrangement, and, in respect to phosphorus and potassium, a recalculation and adaptation of data presented in that bulletin, and thankful acknowledgment of our indebtedness is tendered at this time. Such estimates are very useful, but must be recognized as only approximations. Our experience with fertilizers, thus far, in this state has not been sufficient to afford a basis for recommendations, and those of Van Slyke are offered as a valuable convenience, for use until local observations shall suggest modifications. The figures given cover the range between a moderate application and a very heavy one.

TABLE III. Showing in pounds per acre the quantities of the elements suggested for use in available form, in fertilizers for the crops indicated.

CROPS.	Nitrogen.	Phosphorus.	Potassium.	CROPS.	Nitrogen.	Phosphorus.	Potassium.
Alfalfa	5-10	12.5-25	30- 60	Lettuce	40-80	20-40	60-120
Apples	8-16	12.5-25	40- 80	Millet	15-30	12.5-25	30 -60
Asparagus	20-40	12.5-25	30- 60	Muskmelons	30-60	20-40	50-100
Barley	12-24	8.5-17	20- 40	Nursery stock	10-20	10-20	25- 50
Beans	5-10	12.5-25	30- 60	Oats	12-24	8.5-17	25- 50
Beets	20-40	10-20	30- 60	Onions	45-90	25-50	70-140
Blackberries	15-30	12.5-25	30- 60	Parsnips	20-40	25-50	40- 80
Buckwheat	15-30	12.5-25	30- 60	Peaches	15-30	17.5-35	45- 90
Cabbage	40-80	30-60	75-150	Pears	8-16	12.5-25	40- 80
Carrots	15-30	15-30	35- 70	Peas	5-10	12.5-25	30- 60
Cauliflower	40-80	30-60	75-150	Plums	10-20	15-30	35- 70
Celery	40-80	20-40	50-100	Potatoes	30-60	17.5-35	55-110
Cherries	10-20	15-30	35- 70	Pumpkins	30-60	20-40	50-100
Clover	5-10	12.5-25	30- 60	Quinces	8-16	12.5-25	40- 80
Corn	10-20	15-30	25- 50	Radishes	15-30	15-30	35- 70
Cucumbers	30-60	20-40	50-100	Raspberries	12-24	17.5-35	50-100
Currants	10-20	10-20	30- 60	Rye	12-24	8.5-17	25- 50
Egg plant	40-80	20-40	75-150	Sorghum	10-20	15-30	25- 50
Flax	10-20	10-20	25- 50	Spinach	15-30	25-50	35- 70
Gooseberries	10-20	10-20	30- 60	Squashes	30-60	20-40	50-100
Grapes	8 16	12.5-25	35- 70	Strawberries	25-50	25-50	60 120
Grass for pastures	15-30	12.5-25	30- 60	Tobacco	30-60	20-40	60-120
Grass for lawns	20-40	10-20	25- 50	Tomatoes	25-50	15-30	30- 60
Grass for meadows	15-30	12.5-25	30- 60	Turnips	20-40	10-20	30- 60
Hops	20-40	15-30	80-160	Watermelons	30-60	20-40	50-100
Horse-radish	15-30	10-20	30- 60	Wheat	12-24	8.5-17	10- 20

THE VALUATION OF FERTILIZERS.

The cost of fertilizers varies considerably, depending upon distance from the source of supply, labor expended in their preparation, interest on capital, profit of dealers, etc. Not only does the price of a given material vary, but the cost of a particular element varies, depending on the mode of combination in which it is purchased. This is due in part to the greater availability of the element in certain forms over that of others, and the consequent difference in esteem in which the several forms are held.

Since the relative adaptability of a given element in the different compounds in which it may be obtained is not the same for all crops, it will never be possible to calculate exactly the relative value of the element in these different forms. For the sake of making approximate comparisons, however, chemists for many years have been making estimates of the value of fertilizers. The chemists and directors of several experiment stations agree annually upon the valuation to be used for the current year. By means of these valuations it is possible to calculate approximately the relative worth of the various brands of fertilizers on the market and to avoid the purchase of those which are evidently deficient in value for the price asked.

The valuations adopted are based upon the selling price on the Atlantic seaboard of the raw materials from which fertilizers are manufactured, and hence do not include any of the cost of manufacture. The valuation adopted for 1910 by the experiment stations of Maine, Vermont, Massachusetts, Rhode Island and Connecticut are shown in the accompanying table. For New Jersey the valuations are the same with one slight exception made necessary by a legally prescribed difference in the mode of analysis of phosphates.

TABLE IV. Showing schedule of trade values for 1910.

	Cents per pound.
Nitrogen in nitrates	16
Nitrogen in ammonium salts	16
Organic nitrogen in dry and fine-ground fish, meat and blood and in mixed fertilizers	20
Organic nitrogen in fine bone and tankage	20
Organic nitrogen in coarse bone and tankage	15
Phosphorus in water-soluble phosphates	10.3
Phosphorus in ammonium citrate-soluble phosphates and in fine-ground bone and tankage	9.16
Phosphorus in coarse bone and tankage, cottonseed meal, castor pomace and ashes	8.02
Phosphorus in phosphate insoluble in ammonium citrate, mixed fertilizers	4.58
Potassium in high-grade potassium sulphate and in forms free from chlorides (muriates)	6.02
Potassium in potassium chloride (muriate)	5.12

The valuations shown for phosphorus and potassium have been calculated from the round numbers adopted for "phosphoric acid" and "potash." For all practical purposes, the figures given above may be rounded off to the nearest tenth.

The meaning of these valuations must not be mistaken. They are based on the cost of materials, not on the returns that they yield in crops. The return received following the use of a fertilizer depends on many things beside the fertilizer itself. Among the most important of these is the crop treated. A crop which sells at a low price will return a much smaller additional profit for a certain weight of increased yield than will a crop which sells at a high price. Furthermore, the farmer may at considerable expense use a fertilizer that is not especially adapted to the requirements of the crop to which it is applied. Again, he may apply certain constituents to a soil already well supplied with them, and then not even get an additional yield. The returns attending the use of a fertilizer are thus seen to be dependent upon the business intelligence of the user, and this must be applied to all phases of the problem, not merely to a consideration of the fertilizer.

THE FERTILIZING CONSTITUENTS OF CROPS.

The fact that crops carry off considerable amounts of potassium, nitrogen, phosphorus, etc., is the chief reason why, in many places, it is necessary to add these elements to the soil. Western farmers are all too frequently altogether ignorant or indifferent in respect to the fertilizer valuations represented in their crops, the actual money outlay that would be required to return to the soil in commercial forms the elements removed by them.

The amount removed by a crop cannot be accurately calculated, as plants vary in composition from several causes, the composition of the soil being one. Several chemists have made estimates based on available data. These differ considerably, but most of the accompanying table gives figures that have been calculated from one published by Snyder.

To these we have added a column showing what the indicated quantities of potassium, nitrogen and phosphorus would cost if purchased in fertilizers. For this calculation we have used the valuations previously presented for these elements.

TABLE V. Pounds per acre and value of plant food removed by certain crops.

CROPS.	Gross yield. lbs.	Nitrogen.		Phosphorus.		Potassium.		Calcium.		Silica.	Total ash.	Total value of nitrogen, phosphorus & potassium
		Lbs.	Cost.	Lbs.	Cost.	Lbs.	Cost.	Lbs.	Cost.			
Wheat, 20 bu........	1,200	25	$5 00	5.46	$0 44	5.81	$0 35	0 71	$0.004	1.0	25	$5 79
Straw..	2,000	10	2 00	3.27	26	23.24	1 40	5.00	.025	115.0	185	3 66
Total........................		35	7 00	8.73	70	29 05	1 75	5.71	.029	116.0	210	9 45
Barley, 40 bu.........	1,920	28	5 60	6.55	52	6 60	40	0 71	.004	12 0	40	6 52
Straw................	3,000	12	2 40	2.18	17	24 90	1 50	5 71	.028	60 0	176	4 07
Total........................		40	8 00	8.73	70	31 50	1 90	6.42	.032	72 0	216	10 59
Oats.................	1,600	35	7 00	5.24	42	8.30	50	1.07	.005	15 0	55	7 92
Straw................	3,000	15	3 00	2 62	21	29 10	1 75	6.78	.034	60 0	150	4 96
Total........................		50	10 00	7 86	63	37 40	2 25	7.85	.039	75.0	205	12 88
Corn, 65 bu	2,200	40	8 00	7 86	63	12 45	75	0.71	004	1 0	40	9 38
Stalks...............	3,000	35	7 00	0.87	07	37 35	2 25	7.85	.039	89 0	160	9 32
Total........................		75	15 00	8.73	70	49.80	3 00	8.56	.043	90.0	200	18 70
Peas, 30 bu	1,800	......	....	7 86	63	18.30	1 10	2 85	.014	1.0	64	1 73
Straw..	3,500	......	....	3.06	25	31.50	1 90	150.71	.754	9 0	176	2 14
Total........................		......	....	10 92	87	49 80	3 00	153 56	.768	10.0	240	3 87
Mangels, 10 tons.....	20,000	75	15 00	15.28	1 22	12 45	75	21 42	.107	10 0	350	16 97
Meadow hay, 1 ton ..	2,000	30	6 00	8.73	70	37.40	2 25	8.59	.043	50.0	175	8 95
Clover, 2 tons........	4,000	......	....	12 23	98	54 80	3 30	53 57	.268	15.0	250	4 28
Alfalfa, 4 tons.......	8,000	......	....	13 75	1 10	200.80	12 09	85.44	.427	....	......	13 19
Potatoes, 150 bu	9,000	40	8 00	8 73	70	62 30	3 75	17 85	.089	40.0	125	12 45
Flax, 15 bu..........	900	39	7 80	6 55	52	6 60	40	2.14	.011	0.5	34	8 72
Straw................	1,800	15	3 00	1.31	11	15.80	95	9 29	.046	3.0	53	4 06
Total........................		54	10 80	7 86	63	22.40	1 35	11.43	.057	3.5	87	12 78

FERTILIZING ELEMENTS IN THE FOOD CONSUMED BY DOMESTIC ANIMALS.

From the data presented in table V it is evident that considerable quantities of the important elements of soil fertility are contained in the food consumed by domestic animals. The actual commercial value of this is not fully realized by most farmers, and the value of farm manures as compared with commercial fertilizers is not appreciated.

The percentages of fertilizing elements in farm manures vary greatly, depending upon the care with which they are protected, the character of the feed consumed by the animals and the extent to which rotting has progressed or water evaporated. The figures for the fertilizing constituents are always low, but they are present in readily available form and the accompanying organic matter has itself a highly beneficial effect on the land. Even with these low percentages the total amount of plant food in the manure produced on a farm reaches very significant quantities. The following table has been calculated from the observations of several different men and may serve to bring out strongly the value of this neglected farm product:

TABLE VI. Fertilizer constituents voided by one animal per annum, and value, taking nitrogen at 20 cents, phosphorus at 8 cents, and potassium at 6 cents per pound.

		Nitrogen.	Phos-phorus.	Potassium.	Value.
Horse,	Amount	125 20	20 90	35.90	
	Value	$25 04	$1.67	$2 15	$28.86
Cow,	Amount	170 60	11 40	89 30	
	Value	$34 12	$0.91	$5 36	40 49
Sheep,	Amount	8 40	2 40	11 90	
	Value	$1 68	$0 19	$0 71	2 58
Pig,	Amount	11 90	4 60	9 90	
	Value	$2 38	$0 37	$0 59	3 34

CHOOSING FERTILIZERS.

After a farmer has decided to try the effect of commercial fertilizers upon a given crop the problem of deciding upon the ones to be used is likely to present considerable difficulty. The tables given in this bulletin are designed to reduce the work in this connection to a minimum, but it must be recognized that the use of fertilizers is an application of science in agriculture, and to do this economically and with profitable results requires intelligent thought. Table III shows approximately the quantities of the several elements that may be used, but specific knowledge of the deficiencies of one's soil as shown by analysis or by test crops may point directly to important modifications of those figures.

Furthermore, it may be difficult to choose from among the fertilizers registered in this state, and especially the limited number on sale in one's own town, one that will contain the nitrogen, phosphorus and potassium in the proper proportions. From these points of view it is not infrequently advantageous to the farmer to buy fertilizers containing the elements which he desires and mix them himself. Possibly one of the ready-mixed fertilizers available may be modified by mixing with it a certain amount of one or more other fertilizers, thereby bringing the amounts of the several constituents to the desired relation. In making such calculations table VII will often be found extremely useful.

MIXING FERTILIZERS AT HOME.

If, by means of test crops or otherwise, the farmer has arrived at a definite conclusion concerning the fertilizer that he wishes to apply, it may be almost necessary for him to purchase the raw materials and mix them himself. If so he should bear in mind that they should be as finely ground as practicable and that he must mix them with extreme care if the product is to fulfill his expectations. Unless a uniform mixture is made the several constituents of the fertilizers will not be distributed in the same relative amounts over his fields. Unless they are finely ground they cannot be perfectly mixed, nor uniformly distributed through the soil, and hence the crops cannot profit by them to the same extent.

For mixing fertilizers on the farm all that is required is a smooth floor, shovels, and a screen of three or four meshes to the linear inch. The fertilizers purchased, though they may have been finely ground, are liable to pack in the bags and become lumpy. The rather coarse screen specified is for the purpose of separating these lumps, which must be pounded up until all will pass the screen.

In mixing, the most bulky of the fertilizers is first spread out evenly on the floor in a layer a few inches thick. The next in bulk is then spread evenly over this, and so on until all are spread out. The mass is then shoveled to one side in a ridge or pyramid in such a manner as to mix the different parts as much as possible. The shoveling is repeated two or three times, making three or four shovelings of it all together.

Analyses made of home mixtures so prepared have shown that satisfactory uniformity in composition may be obtained, and field experiments with such fertilizers have given results equal to those afforded by factory-mixed fertilizers of the same composition. The saving in cash outlay is considerable and is well worth attention. One should not undertake home mixing, however, unless equipped to do the work properly and willing to give it sufficient attention to see that it is well done.

FUNDAMENTAL COMMERCIAL FERTILIZERS.

In the preparation of mixed fertilizers, either by large manufacturers or by the farmer for his own use, certain substances are available in considerable quantities. For the convenience of the farmer a table is given herewith showing the composition of these that he may have something to guide him in choosing. The different ones are grouped according to the element for which the fertilizer is employed, chiefly, though it will be seen that some contain more than one element and all must be taken into account in calculating the formula for a mixed fertilizer. The figures for commercial fertilizers are calculated from a table published by Voorhees in Farmer's Bulletin No. 44, United States Department of Agriculture. A statement concerning the composition of farm manures is also included for comparison and for general reference. Farm manures vary enormously in composition, depending to a certain extent on the species of the animal, but more on the feed of the animal, the amount of water in the manure, the amount of bedding, whether or not both solid and liquid excretions are included, and the extent to which fermentation has taken place. The figures given are the average of selections made from Storer's compilation, and apply to fresh or nearly fresh manures, free from litter. As an average for well-kept mixed barnyard manure from cattle, one may without serious error assume a composition of 0.5 per cent nitrogen, 0.14 per cent phosphorus and 0.42 per cent potassium. A similar product from horses may be taken as containing 0.5 per cent nitrogen, 0.11 per cent phosphorus and 0.40 potassium.

TABLE VII. Showing composition of principal commercial fertilizing materials and farm manures.

	Nitrogen.	Phosphorus in— Available phosphates.	Insoluble phosphates.	Total phosphates.	Potassium.	Chlorine.
NITROGENOUS.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sodium nitrate (Chili saltpeter, nitrate of soda)	15.5 to 16.0	...	...	...	...	...
Ammonium sulphate (sulphate of ammonia)	19.0 to 20.5	...	...	...	...	...
Dried blood, high grade	12.0 to 14.0	...	...	...	...	...
Dried blood, low grade	10 0 to 11.0	...	...	1.3 to 2.2	...	...
Concentrated tankage	11.0 to 12.5	...	...	0.4 to 0.9	...	...
Bone tankage	5.0 to 6.0	...	...	4.8 to 6.1	...	...
Dried fish scraps	7.0 to 9.0	...	...	2.6 to 3.5	...	...
Cottonseed meal	6.5 to 7.5	...	...	0.6 to 0.9	1.7 to 2.5	...
Castor-bean pomace	5.0 to 6.0	...	...	0.4 to 0.6	0.8 to 1.2	...
PHOSPHATIC.						
South Carolina rock phosphate	...	...	11.4 to 12.2	11.4 to 12.2	...	...
South Carolina rock superphosphate (dissolved S. C. rock phosphate)	...	5.2 to 6.5	0.4 to 1.3	5.7 to 7.0	...	...
Florida land rock phosphate	...	...	14.4 to 15.3	14.4 to 15.3	...	...
Florida pebble phosphate	...	...	11.4 to 14.0	11.4 to 14.0	...	...
Florida superphosphate (dissolved Florida phosphate)	...	6.1 to 7.0	0.4 to 1.7	7.0 to 8.7	...	...
Bone black	...	...	14.0 to 15.7	14.0 to 15.7	...	...
Bone black superphosphate (dissolved bone black)	...	6.5 to 7.4	0.4 to 0.9	7.4 to 7.9	...	...
Ground bone	2.5 to 4 5	2.2 to 3.5	6.5 to 7.4	8.7 to 10.9	...	...
Steamed bone	1.5 to 2.5	2.6 to 3.9	7.0 to 8.7	9.6 to 12.7	...	...
Dissolved bone	2.0 to 3.0	5.7 to 6.5	0.9 to 1.3	6.5 to 7.4	...	...
Thomas slag	...	...	...	5.0 to 10 0	...	...

Potassic.						
Potassium chloride (muriate of potash)	....	....	....	....	41.5	45.0 to 48.0
Potassium sulphate, high grade (sulphate of potash)	....	....	....	....	39.8 to 43.2	0.5 to 1.5
Potassium magnesium sulphate (sulphate of potash and magnesia)	....	....	....	....	21.6 to 24.9	1.5 to 2.5
Kainite	....	....	....	....	10.0 to 10.4	30.0 to 32.0
Sylvinite	....	....	....	....	13.3 to 16.6	42.0 to 46.0
Cottonseed-hull ashes	....	....	....	3.1 to 3.9	16.6 to 24.9	....
Wood ashes, unleached	....	....	....	0.4 to 0.9	1.7 to 6.6	....
Wood ashes, leached	....	....	....	0.4 to 0.6	0.8 to 1.7	....
Tobacco stems	2 0 to 3.0	....	....	1.3 to 2.2	4.2 to 6.6	....
Farm Manures.						
Cattle dung	0.40	0 09	....	0.09	0.17	....
Horse "	0 58	0.16	....	0.16	0.43	....
Poultry "	1.60	0.65	....	0.65	0.71	....
Sheep "	0.63	0.17	....	0.17	0.87	....
Swine "	0.61	0.16	....	0.16	0.82	....
Cattle urine	0.90	0.006	....	0.006	1.10	....
Horse "	1.70	trace	....	trace	1.05	....
Sheep "	1.20	0.013	....	0.013	1.05	....
Swine "	0.43	0.05	....	0.05	0.38	....

HOW TO CALCULATE THE QUANTITIES OF FERTILIZERS TO BE APPLIED.

Unless previous plot testing has shown the nature of the deficiency in one's soil, the quantities of nitrogen, potassium and phosphorus to be applied to the several crops may be determined by consulting table III. For example, the amounts recommended for potatoes are: 30 to 60 pounds of nitrogen, 17.5 to 35 of phosphorus and 55 to 110 of potassium.

These elements, however, cannot be applied as such, and would be useless or injurious if so applied. Plants get them in various compounds, such as nitrates, ammonium salts, organic waste products, phosphates, potassium salts, etc. These substances as they occur in commerce vary considerably in their content of the desired constituents, and certain arithmetical calculations are necessary in order to ascertain the quantities of any one to be used to apply the desired amounts of nitrogen, potassium or phosphorus, as the case may be. While these calculations are not difficult, table VIII has been prepared that the labor of making them may be reduced to a minimum.

Suppose that it has been decided to apply fertilizers carrying 45 pounds of nitrogen, 26 of phosphorus and 80 of potassium in available forms. These amounts might be supplied by various substances as shown by table VII. The calculation is simplest if the materials chosen are such that each furnishes but one of the fertilizing elements. For example, sodium nitrate might be chosen to supply nitrogen, Florida superphosphate for phosphorus and potassium sulphate for potassium. Their composition may, for illustration, be assumed to be 15.8 per cent nitrogen in the nitrate, 7 per cent available phosphorus in the superphosphate, and 42.2 per cent .potassium in the potassium sulphate.

By referring to table VIII, in the columns marked "percentage present" one finds the numbers 15.8, 7.0 and 42.2, and opposite these to the right, in columns headed "pounds required," he finds the corresponding weights necessary to furnish one pound, viz., 6.33 pounds of the sodium nitrate for one pound of nitrogen, 14.3 pounds of the superphosphate for one pound of phosphorus, and 2.37 pounds of the potassium sulphate for one pound of potassium. The total amount of each required is found by multiplying the amount that contains one pound by the pounds of the element required in each case. Thus:

6.33 x 45 = 284.9 sodium nitrate,
14.30 X 26 = 371.8 superphosphate,
2.37 X 80 = 189.6 potassium sulphate.

If, however, one wishes to use dissolved bone as the source of the phosphorus he must take account also of the nitrogen in it. Suppose that it contains 2.5 per cent of nitrogen and 6.4 per cent of phosphorus in available form. A little thought will show that although it contains nitrogen it cannot be used as the sole source of that element without adding much more phosphorus than desired, for it is proposed to apply 45 of nitrogen and 26 of phosphorus, or nearly twice as much nitrogen as phosphorus, while in the dissolved bone there is over twice as much phosphorus as nitrogen.

The first step then is to compute the amount of the dissolved bone necessary to furnish the 26 pounds of phosphorus. By reference again to table VIII one finds that with a percentage of 6.4, 15.6 pounds will be required to give one pound of phosphorus. The total weight required would be 15.6 x 26 = 405.6 pounds. As this contains 2.5 per cent of nitrogen, the quantity of that element contained in the bone is found by multiplying by the rate per cent and dividing by 100. Thus, $\frac{405.6 \times 2.5}{100} = 10.14$, which is the number of pounds of nitrogen in the 405.6 pounds of bone. As the total nitrogen to be applied is 45 pounds, 45 - 10.14 = 34.86, the number of pounds to be supplied by other means. This might be by a concentrated tankage carrying 12.5 per cent of nitrogen. By means of table VIII it is seen that of such tankage eight pounds will be needed to supply one pound of nitrogen. To supply 34.86 pounds, 34.86 x 8 = 278.88 pounds will be required.

If now we suppose that the potassium is to be furnished by means of unleached wood ashes containing 5.9 per cent of potassium, we see by table VIII that 17 pounds of the ashes will be necessary for each pound of potassium to be supplied. Hence 80 x 17 = 1360 is the number of pounds required with the 405.6 pounds of dissolved bone and 278.88 pounds of concentrated tankage, to supply 80 pounds of potassium, 26 of phosphorus and 45 of nitrogen. The bone and tankage also carry small quantities of phosphorus in forms not rated as available, but which are of value, as natural processes will gradually change them to available compounds.

On principles similar to those illustrated above the quantities required of any fertilizers chosen may be computed, and any desired amounts of nitrogen, phosphorus and potassium supplied in the mixture thus calculated.

FILLER IN FERTILIZERS.

There is likely to be an important misconception in reference to the amount of inert material in fertilizers as sold. Thus if a fertilizer is guaranteed to contain 7 per cent phosphorus, 8 of potassium and 4 of nitrogen, the first impression must be that the remaining 81 per cent is unnecessary "filler." The farmer may think that he is being cheated as to quality, and in any event is obliged to pay freight on worthless material. This view may at times or to a certain extent have a real justification, but it may be unfounded for the most part. Let us see how this comes about.

The elements phosphorus, potassium and nitrogen are never used in the pure, free state as fertilizers. Nitrogen is a gas, and abundantly present in the air but cannot be appropriated by any field crops except the legumes. Phosphorus and potassium would be wholly unfit to apply to land in the free state, and are very costly to prepare from their compounds even if the elements themselves as such were suitable to put on the soil. These elements are merely the measures of value of the considerable variety of their compounds present in soils and fertilizers. These compounds are the real fertilizing substances and the other elements combined in them with the nitrogen, phosphorus and potassium are necessarily present in order that these three may be supplied to plants in a form that can be taken up and utilized. Examples may make this plainer.

Sodium nitrate or Chili saltpeter is one of the most valuable nitrogenous fertilizers. In the pure state it contains 16.5 per cent of nitrogen. It might seem that, if nitrogen is the element that it is desired to offer the crop, the remainder of the substance is "filler." This view would be quite wrong, however, as the sodium and the oxygen that make up the remaining 83.5 per cent are essential to the existance of the Chili saltpeter.

Similarly, potassium chloride, or "muriate of potash," another compound largely used in fertilizers, is only 52.3 per cent potassium, but the 47.7 per cent of chlorine present is as necessary to the formation of potassium chloride as is the potassium itself.

Again, if a superphosphate should be prepared from pure calcium phosphate and sulphuric acid it would contain only 12.2 per cent of phosphorus. It would also contain 23.7 per cent of calcium, which in some soils would be a valuable element to add. Even counting that, the sulphur, hydrogen and oxygen, constituting the remainder of the superphosphate and without which it could not exist, make up 64.1 per cent of the substance.

A fertilizer compounded of 1200 pounds of such pure superphosphate, 500 pounds of pure sodium nitrate and 300 pounds of pure potassium chloride per ton, would be a perfectly pure fertilizer, yet it would contain in the aggregate only 7.3 per cent of phosphorus, 7.8 of potassium and 4.1 of nitrogen, or 19.2 per cent all together. The remaining elements are unavoidably present, as plants cannot utilize the free elements, but must receive them in compounds such as those named.

It will be seen that even with perfectly pure fertilizing substances it is impossible to avoid a large percentage of seemingly useless elements. However, substances as they occur in nature are seldom pure, and the cost of purifying them is often very large. The phosphate rock of Florida, South Carolina and Tennessee is on the average much below pure calcium phosphate in its content of phosphorus, and to purify completely these natural products is not economically possible. It is much better to sell them in a somewhat impure condition, either with or without previous conversion into superphosphate, and pay freight on useless material, than to go to the great expense of putting the rock through a long and costly chemical process for its purification. Similar considerations apply to nitrogenous and potassic fertilizing materials also. One is, therefore, not in position to condemn a fertilizer as weighted with worse than useless "filler" until he knows what substances have been used as the source of the several elements of fertility and has made a somewhat troublesome arithmetical calculation.

It should also be clear that the valuation of any fertilizer can be made only by taking into consideration the percentage of the fertilizing elements, and that a guaranty concerning them is essential as a safeguard to the purchaser. It will also be seen that high-grade fertilizers are not only worth more because of their higher content of the fertilizing elements, but that pound for pound these elements are worth somewhat more in such fertilizers by reason of the saving in freight and handling.

EXPLANATION OF THE USE OF TABLE VIII.

Table VIII requires but little explanation. Although included here because of its applicability in making computations relative to fertilizers, it presents purely mathematical relations that may be used in connection with anything else. Really the figures in the columns headed "pounds required'' are the reciprocals of numbers one one-hundredth as large as the numbers opposite under the heading "percentage present." Thus 1000 is the reciprocal of 0.001, 500 of 0.002, 125 of 0.008, 20 of 0.05, etc. This table has been made up by adapting and extending a table of reciprocals of numbers given in Holman's "Computation Rules and Logarithms."

Suppose that the farmer has decided to apply in a certain case 500 pounds of phosphorus to land, and to supply this in the form of a finely ground rock phosphate containing 13.5 per cent of phosphorus. By looking in table VIII, in the columns, headed "percentage present," until the figures 13.5 are reached, one finds opposite, to the right, in the column headed "pounds required,'' the number 7.407. From this he knows that 7.401 pounds of the phosphate rock containing 13.5 per cent of phosphorus will furnish one pound of phosphorus; hence to get the 500 pounds of phosphorus required he must obtain 500 times 7.407, or 3703.5 pounds.

Suppose, on the other hand, that his data are stated in figures for "phosphoric acid" instead of phosphorus, and that he has decided to use 1145 pounds of "phosphoric acid" on his land, and that the rock phosphate that he has in view contains 30.9 per cent of "phosphoric acid." By finding in table VIII under "percentage present" the number 30.9, he finds opposite, to the right, under "pounds required,'' the number 3.236. This shows the number of pounds of the rock phosphate required to furnish one pound of phosphoric acid, and by multiplying 1145 by 3.236 he finds that 3705.2 pounds of the rock phosphate will be required. This result differs slightly from the one calculated from the figures for phosphorus, because in both cases small fractions have been dropped off.

Again, suppose that the farmer has decided to apply 500 pounds of phosphorus, but that in quoting prices to him the rock phosphate is guaranteed to contain 30.9 per cent of "phosphoric acid," how shall he proceed to ascertain the number of pounds necessary? He may find the amount of "phosphoric acid" equivalent to the 500 pounds of phosphorus by consulting table IX, thus finding it to be 1145 pounds. He will then continue as just described and compute the number of pounds of phosphate containing 30.9 per cent of "phosphoric acid" required to furnish 1145 pounds of "phosphoric acid." On the other hand, he may ascertain the percentage of phosphorus equivalent to 30.9 per cent of "phosphoric acid" by the use of table IX. This will be found to be 13.5, and the computation may be made as first described.

As already indicated, table VIII may be used for other purposes. If one knows the percentage of protein in a feed he can read off the number of pounds necessary to furnish one pound of protein. Thus if an alfalfa hay contains 12.3 per cent of protein, the table shows that 8.13 pounds of the hay will contain one pound of the protein.

If a lot of sugar beets contains 15.7 per cent of sugar the table shows that 6.369 pounds of the beets would contain a pound of sugar.

If corn silage contains 23 per cent of dry matter, 4.348 pounds would be required to furnish one pound of dry matter.

If an ore contains 11.2 per cent of copper, 8.929 pounds may be read directly from the table as the weight of ore that contains one pound of copper.

Examples might be multiplied indefinitely, but these will suffice to show the class of problems the solution of which is facilitated by table VIII.

TABLE VIII. Showing the number of pounds of a fertilizer required to furnish one pound of any element when the percentage of that element present in the fertilizer is known.

Percentage present...	Pounds required...	Percentage present...	Pounds required...	Percentage present...	Pounds required...	Precentage present...	Pounds required...
0.1	1000.00	6.4	15.63	12.7	7.874	19.0	5.263
0.2	500.00	6.5	15.38	12.8	7.813	19.1	5.236
0.3	333.33	6.6	15.15	12.9	7.752	19.2	5.208
0.4	250.00	6.7	14.93	13.0	7.692	19.3	5.181
0.5	200.00	6.8	14.71	13.1	7.634	19.4	5.155
0.6	166.67	6.9	14.49	13.2	7.576	19.5	5.128
0.7	142.86	7.0	14.29	13.3	7.512	19.6	5.102
0.8	125.00	7.1	14.08	13.4	7.463	19.7	5.076
0.9	111.11	7.2	13.89	13.5	7.407	19.8	5.051
1.0	100.00	7.3	13.70	13.6	7.353	19.9	5.025
1.1	90.91	7.4	13.51	13.7	7.299	20.0	5.000
1.2	83.33	7.5	13.33	13.8	7.246	20.1	4.975
1.3	76.92	7.6	13.16	13.9	7.194	20.2	4.950
1.4	71.43	7.7	12.99	14.0	7.143	20.3	4.926
1.5	66.63	7.8	12.82	14.1	7.092	20.4	4.902
1.6	62.50	7.9	12.66	14.2	7.042	20.5	4.878
1.7	58.82	8.0	12.50	14.3	6.993	20.6	4.854
1.8	55.56	8.1	12.35	14.4	6.944	20.7	4.831
1.9	52.63	8.2	12.20	14.5	6.897	20.8	4.808
2.0	50.00	8.3	12.05	14.6	6.849	20.9	4.785
2.1	47.62	8.4	11.90	14.7	6.803	21.0	4.762
2.2	45.45	8.5	11.76	14.8	6.757	21.1	4 739
2.3	43.48	8.6	11.63	14.9	6.711	21.2	4.717
2.4	41.67	8.7	11.49	15.0	6.667	21.3	4.695
2.5	40.00	8.8	11.36	15.1	6.623	21.4	4.673
2.6	38.46	8.9	11.24	15.2	6 579	21.5	4.651
2.7	37.04	9.0	11.11	15.3	6.536	21.6	4.630
2.8	35 71	9.1	10.99	15.4	6.494	21.7	4.608
2.9	34.48	9.2	10.87	15.5	6.452	21.8	4.587
3.0	33.33	9.3	10.75	15.6	6.410	21.9	4.566
3.1	32.26	9.4	10.64	15.7	6.369	22.0	4.545
3.2	31.25	9.5	10.53	15.8	6.329	22.1	4.525
3.3	30.30	9.6	10.42	15.9	6.289	22.2	4.505
3 4	29.41	9.7	10.31	16.0	6.250	22.3	4.484
3.5	28.57	9.8	10.20	16.1	6.211	22.4	4.464
3.6	27.78	9.9	10.10	16.2	6.173	22.5	4.444
3.7	27.03	10.0	10.00	16.3	6.135	22.6	4.425
3.8	26.32	10.1	9.901	16.4	6.098	22.7	4.405
3.9	25.64	10.2	9.804	16.5	6.061	22.8	4.386
4.0	25.00	10.3	9.709	16.6	6.024	22.9	4.367
4.1	24.39	10.4	9.615	16.7	5.988	23.0	4.348
4.2	23.81	10.5	9.524	16.8	5.952	23.1	4.329
4.3	23.26	10.6	9.434	16.9	5.917	23.2	4.310
4.4	22.73	10.7	9.346	17.0	5.882	23.3	4.292
4.5	22.22	10.8	9.259	17.1	5.848	23.4	4.274
4.6	21.74	10.9	9.174	17.2	5.814	23.5	4.255
4.7	21.28	11.0	9.091	17.3	5.780	23.6	4.237
4.8	20.83	11.1	9.009	17.4	5.747	23.7	4.219
4.9	20.41	11.2	8.929	17.5	5.714	23.8	4.202
5.0	20.00	11.3	8.850	17.6	5.682	23.9	4.184
5.1	19.61	11.4	8.772	17.7	5.650	24.0	4.167
5.2	19.23	11.5	8.696	17.8	5.618	24.1	4.149
5.3	18.87	11.6	8.621	17.9	5.587	24.2	4.132
5.4	18.52	11.7	8.547	18.0	5.556	24.3	4.115
5.5	18.18	11.8	8.475	18.1	5.525	24.4	4.098
5.6	17.86	11.9	8.403	18.2	5.495	24.5	4.082
5.7	17.54	12.0	8.333	18.3	5.464	24.6	4.065
5.8	17.24	12.1	8.264	18.4	5.435	24.7	4.049
5.9	16.95	12.2	8.197	18.5	5.405	24.8	4.032
6.0	16.67	12.3	8.130	18.6	5.376	24.9	4.016
6 1	16.39	12.4	8.065	18.7	5.348	25.0	4.000
6.2	16.13	12 5	8.000	18.8	5.319		
6.3	15.87	12.6	7.937	18.9	5.291		

TABLE VIII—*Continued.*

Percentage present. . .	Pounds required. . .	Percentage present. . .	Pounds required. . .	Percentage present. . .	Pounds required. . .	Percentage present. . .	Pounds required. . .
25.1	3.984	31.4	3.185	37.7	2.653	44.0	2.273
25.2	3.968	31.5	3.175	37.8	2.646	44.1	2.268
25.3	3.953	31.6	3.165	37.9	2.639	44.2	2.262
25.4	3.937	31.7	3.155	38.0	2.632	44.3	2.257
25.5	3.922	31.8	3.145	38.1	2.625	44.4	2.252
25.6	3.906	31.9	3.135	38.2	2.618	44.5	2.247
25.7	3.891	32.0	3.125	38.3	2.611	44.6	2.242
25.8	3.876	32.1	3.115	38.4	2.604	44 7	2.237
25.9	3.861	32.2	3.106	38.5	2.597	44.8	2.232
26.0	3.846	32.3	3.096	38.6	2.591	44.9	2.227
26.1	3.831	32.4	3.086	38.7	2.584	45.0	2.222
26.2	3.817	32.5	3.077	38.8	2.577	45.1	2.217
26.3	3.802	32.6	3.067	38.9	2.571	45.2	2.212
26.4	3.788	32.7	3.058	39.0	2.564	45.3	2.208
26.5	3.774	32.8	3.049	39.1	2.558	45.4	2.203
26.6	3.759	32.9	3.040	39.2	2.551	45.5	2.198
26.7	3.745	33.0	3.030	39.3	2.545	45.6	2.193
26.8	3.731	33.1	3.021	39.4	2.538	45.7	2.188
26.9	3.717	33.2	3.012	39.5	2.532	45.8	2.183
27.0	3.704	33.3	3.003	39.6	2.525	45.9	2.179
27.1	3.690	33.4	2.994	39 7	2.519	46.0	2.174
27.2	3.676	33.5	2.985	39.8	2.513	46.1	2.169
27.3	3.663	33.6	2.976	39.9	2.506	46.2	2.165
27.4	3.650	33.7	2.967	40.0	2.500	46.3	2.160
27.5	3.636	33.8	2.959	40.1	2.494	46.4	2.155
27.6	3.623	33.9	2.950	40.2	2.488	46.5	2.151
27.7	3.610	34.0	2.941	40.3	2.481	46.6	2.146
27.8	3.597	34.1	2.933	40.4	2.475	46.7	2.141
27.9	3.584	34.2	2.924	40.5	2.469	46.8	2.137
28.0	3.571	34.3	2.915	40.6	2.463	46 9	2.132
28.1	3.559	34.4	2.907	40.7	2.457	47.0	2.128
28.2	3.546	34.5	2.899	40.8	2.451	47.1	2.123
28.3	3.534	34.6	2.890	40.9	2.445	47.2	2.119
28.4	3.521	34.7	2.882	41.0	2.439	47.3	2.114
28.5	3.509	34.8	2.874	41.1	2.433	47.4	2.110
28.6	3.497	34.9	2.865	41.2	2.427	47.5	2.105
28.7	3.484	35.0	2.857	41.3	2.421	47.6	2.101
28.8	3.472	35.1	2.849	41.4	2.415	47.7	2.096
28.9	3.460	35.2	2.841	41.5	2.410	47.8	2.092
29.0	3.448	35.3	2.833	41.6	2.404	47.9	2.088
29.1	3.436	35.4	2.825	41.7	2.398	48.0	2.083
29.2	3.425	35.5	2.817	41.8	2.392	48.1	2.079
29.3	3.413	35.6	2.809	41.9	2.387	48.2	2.075
29.4	3.401	35.7	2.801	42.0	2.381	48.3	2.070
29.5	3.390	35.8	2.793	42.1	2.375	48.4	2.066
29.6	3.378	35.9	2.786	42.2	2.370	48.5	2.062
29.7	3.367	36.0	2.778	42.3	2.364	48.6	2.058
29.8	3.356	36.1	2.770	42.4	2.358	48.7	2.053
29.9	3.344	36.2	2.762	42.5	2.353	48.8	2.049
30.0	3.333	36.3	2.755	42.6	2.347	48.9	2.045
30.1	3.322	36.4	2.747	42.7	2.342	49.0	2.041
30.2	3.311	36.5	2.740	42.8	2.336	49.1	2.037
30.3	3.300	36.6	2.732	42.9	2.331	49.2	2.033
30.4	3.289	36.7	2.725	43.0	2.326	49.3	2.028
30.5	3.279	36.8	2 717	43.1	2 320	49.4	2.024
30.6	3.268	36.9	2.710	43.2	2.315	49.5	2.020
30.7	3.257	37.0	2.703	43.3	2.309	49.6	2.016
30.8	3.247	37.1	2.695	43.4	2.304	49.7	2.012
30.9	3.236	37.2	2.688	43.5	2.299	49.8	2.008
31.0	3.226	37.3	2.681	43.6	2.294	49.9	2.004
31.1	3.215	37.4	2.674	43.7	2.288	50.0	2.000
31.2	3.205	37.5	2.667	43.8	2.283		
31.3	3.195	37.6	2.660	43.9	2.278		

TABLE VIII—*Continued.*

Percentage present...	Pounds required....	Percentage present...	Pounds required....	Percentage present...	Pounds required....	Percentage present...	Pounds required....
50.1	1.996	56.4	1.773	62.7	1.595	69.0	1.449
50.2	1.992	56.5	1.770	62.8	1.592	69.1	1.447
50.3	1.988	56.6	1.767	62.9	1.590	69.2	1.445
50.4	1.984	56.7	1.764	63.0	1.587	69.3	1.443
50.5	1.980	56.8	1.761	63.1	1.585	69.4	1.441
50.6	1.976	56.9	1.757	63.2	1.582	69.5	1.439
50.7	1.972	57.0	1.754	63.3	1.580	69.6	1.437
50.8	1.969	57.1	1.751	63.4	1.577	69.7	1.435
50.9	1.965	57.2	1.748	63.5	1.575	69.8	1.433
51.0	1.961	57.3	1.745	63.6	1.572	69.9	1.431
51.1	1.957	57.4	1.742	63.7	1.570	70.0	1.429
51.2	1.953	57.5	1.739	63.8	1.567	70.1	1.427
51.3	1.949	57.6	1.736	63.9	1.565	70.2	1.425
51.4	1.946	57.7	1.733	64.0	1.563	70.3	1.422
51.5	1.942	57.8	1.730	64.1	1.560	70.4	1.420
51.6	1.938	57.9	1.727	64.2	1.558	70.5	1.418
51.7	1.934	58.0	1.724	64.3	1.555	70.6	1.416
51.8	1.931	58.1	1.721	64.4	1.553	70.7	1.414
51.9	1.927	58.2	1.718	64.5	1.550	70.8	1.412
52 0	1.923	58.3	1.715	64.6	1.548	70.9	1.410
52.1	1.919	58.4	1.712	64.7	1.546	71.0	1.408
52.2	1.916	58.5	1.709	64.8	1.543	71.1	1.406
52.3	1.912	58.6	1.706	64.9	1.541	71.2	1.404
52.4	1.908	58.7	1.704	65.0	1.538	71.3	1.403
52.5	1.905	58.8	1.701	65.1	1.536	71.4	1.401
52.6	1.901	58.9	1.698	65.2	1.534	71.5	1.399
52.7	1.898	59.0	1.695	65.3	1.531	71.6	1.397
52.8	1.894	59.1	1.692	65.4	1.529	71.7	1.395
52.9	1.890	59.2	1.689	65.5	1.527	71.8	1.393
53.0	1.887	59.3	1.686	65.6	1.524	71.9	1.391
53.1	1.883	59.4	1.684	65.7	1.522	72.0	1.389
53.2	1.880	59.5	1.681	65.8	1.520	72.1	1.387
53.3	1.876	59.6	1.678	65.9	1.517	72.2	1.385
53.4	1.873	59.7	1.675	66.0	1.515	72.3	1.383
53.5	1.869	59.8	1.672	66.1	1.513	72.4	1.381
53.6	1.866	59.9	1.669	66.2	1.511	72.5	1.379
53.7	1.862	60.0	1.667	66.3	1.508	72.6	1.377
53.8	1.859	60.1	1.664	66.4	1.506	72.7	1.376
53.9	1.855	60.2	1.661	66.5	1.504	72.8	1.374
54.0	1.852	60.3	1.658	66.6	1.502	72.9	1.372
54.1	1.848	60.4	1.656	66.7	1.499	73.0	1.370
54.2	1.845	60.5	1.653	66.8	1.497	73.1	1.368
54.3	1.842	60.6	1.650	66.9	1.495	73.2	1.366
54.4	1.838	60.7	1.647	67.0	1.493	73.3	1.364
54.5	1.835	60.8	1.645	67.1	1.490	73.4	1.362
54.6	1.832	60.9	1.642	67.2	1.488	73.5	1.361
54.7	1.828	61.0	1.639	67.3	1.486	73.6	1.359
54.8	1.825	61.1	1.637	67.4	1.484	73.7	1.357
54.9	1.821	61.2	1.634	67.5	1.481	73.8	1.355
55.0	1.818	61.3	1.631	67.6	1.479	73.9	1.353
55.1	1.815	61.4	1.629	67.7	1.477	74.0	1.351
55.2	1.812	61.5	1.626	67.8	1.475	74.1	1.350
55.3	1.808	61.6	1.623	67.9	1.473	74.2	1.348
55.4	1.805	61.7	1.621	68.0	1.471	74.3	1.346
55.5	1.802	61.8	1 618	68.1	1.468	74.4	1.344
55.6	1.799	61.9	1.616	68.2	1.466	74.5	1.342
55.7	1.795	62.0	1.613	68.3	1.464	74.6	1.340
55.8	1.792	62.1	1.610	68.4	1.462	74.7	1.339
55.9	1.789	62.2	1.608	68.5	1.460	74.8	1.337
56 0	1.786	62.3	1.605	68.6	1.458	74.9	1.335
56.1	1.783	62.4	1.603	68.7	1.456	75.0	1.333
56.2	1.779	62.5	1.600	68.8	1.453		
56.3	1.776	62.6	1.597	68.9	1.451		

TABLE VIII—*Concluded.*

Percentage present . . .	Pounds required . . .	Percentage present . . .	Pounds required . . .	Percentage present . . .	Pounds required . . .	Percentage present . . .	Pounds required . . .
75.1	1.332	81.4	1.229	87.7	1.140	94.0	1.064
75.2	1.330	81.5	1.227	87.8	1.139	94.1	1.063
75.3	1.328	81.6	1.225	87.9	1.138	94.2	1.062
75.4	1.326	81.7	1.224	88.0	1.136	94.3	1.060
75.5	1.325	81.8	1.222	88.1	1.135	94.4	1.059
75.6	1.323	81.9	1.221	88.2	1.134	94.5	1.058
75.7	1.321	82.0	1.220	88.3	1.133	94.6	1.057
75.8	1.319	82.1	1.218	88.4	1.131	94.7	1.056
75.9	1.318	82.2	1.217	88.5	1.130	94.8	1.055
76.0	1.316	82.3	1.215	88.6	1.129	94.9	1.054
76.1	1.314	82.4	1.214	88.7	1.127	95.0	1.053
76.2	1.312	82.5	1.212	88.8	1.126	95.1	1.052
76.3	1.311	82.6	1.211	88.9	1.125	95.2	1.050
76.4	1.309	82.7	1.209	89.0	1.124	95.3	1.049
76.5	1.307	82.8	1.208	89.1	1.122	95.4	1.048
76.6	1.305	82.9	1.206	89.2	1.121	95.5	1.047
76.7	1.304	83.0	1.205	89.3	1.120	95.6	1.046
76.8	1.302	83.1	1.203	89.4	1.119	95.7	1.045
76.9	1.300	83.2	1.202	89.5	1.117	95.8	1.044
77.0	1.299	83.3	1.200	89.6	1.116	95.9	1.043
77.1	1.297	83.4	1.199	89.7	1.115	96.0	1.042
77.2	1.295	83.5	1.198	89.8	1.114	96.1	1.041
77.3	1.294	83.6	1.196	89.9	1.112	96.2	1.040
77.4	1.292	83.7	1.195	90.0	1.111	96.3	1.038
77.5	1.290	83.8	1.193	90.1	1.110	96.4	1.037
77.6	1.289	83.9	1.192	90.2	1.109	96.5	1.036
77.7	1.287	84.0	1.190	90.3	1.107	96.6	1.035
77.8	1.285	84.1	1.189	90.4	1.106	96.7	1.034
77.9	1.284	84.2	1.188	90.5	1.105	96.8	1.033
78.0	1.282	84.3	1.186	90.6	1.104	96.9	1.032
78.1	1.280	84.4	1.185	90.7	1.103	97.0	1.031
78.2	1.279	84.5	1.183	90.8	1.101	97.1	1.030
78.3	1.277	84.6	1.182	90.9	1.100	97.2	1.029
78.4	1.276	84.7	1.181	91.0	1.099	97.3	1.028
78.5	1.274	84.8	1.179	91.1	1.098	97.4	1.027
78.6	1.272	84.9	1.178	91.2	1.096	97.5	1.026
78.7	1.271	85.0	1.176	91.3	1.095	97.6	1.025
78.8	1.269	85.1	1.175	91.4	1.094	97.7	1.024
78.9	1.267	85.2	1.174	91.5	1.093	97.8	1.022
79.0	1.266	85.3	1.172	91.6	1.092	97.9	1.021
79.1	1.264	85.4	1.171	91.7	1.091	98.0	1.020
79.2	1.263	85.5	1.170	91.8	1.089	98.1	1.019
79.3	1.261	85.6	1.168	91.9	1.088	98.2	1.018
79.4	1.259	85.7	1.167	92.0	1.087	98.3	1.017
79.5	1.258	85.8	1.166	92.1	1.086	98.4	1.016
79.6	1.256	85.9	1.164	92.2	1.085	98.5	1.015
79.7	1.255	86.0	1.163	92.3	1.083	98.6	1.014
79.8	1.253	86.1	1.161	92.4	1.082	98.7	1.013
79.9	1.252	86.2	1.160	92.5	1.081	98.8	1.012
80.0	1.250	86.3	1.159	92.6	1.080	98.9	1.011
80.1	1.248	86.4	1.157	92.7	1.079	99.0	1.010
80.2	1.247	86.5	1.156	92.8	1.078	99.1	1.009
80.3	1.245	86.6	1.155	92.9	1.076	99.2	1.008
80.4	1.244	86.7	1.153	93.0	1.075	99.3	1.007
80.5	1.242	86.8	1.152	93.1	1.074	99.4	1.006
80.6	1.241	86.9	1.151	93.2	1.073	99.5	1.005
80.7	1.239	87.0	1.149	93.3	1.072	99.6	1.004
80.8	1.238	87.1	1.148	93.4	1.071	99.7	1.003
80.9	1.236	87.2	1.147	93.5	1.070	99.8	1.002
81.0	1.235	87.3	1.145	93.6	1.068	99.9	1.001
81.1	1.233	87.4	1.144	93.7	1.067	100.0	1.000
81.2	1.232	87.5	1.143	93.8	1.066		
81.3	1.230	87.6	1.142	93.9	1.065		

EXPLANATION OF THE USE OF TABLES IX TO XII.

Tables IX to XII have been prepared for the purpose of facilitating the calculation of data stated in the old system into those of the element system, and those of the element system into the old. Each table is double, and gives for each whole number from 1 to 100 of the one substance the equivalent amount of the corresponding other substance. Figures are also given for each of the hundreds from 100 to 1000 for each substance. These tables have been calculated by machine, using the international atomic weights for 1910, and are believed to be absolutely accurate. These atomic weights are: Oxygen, 16; hydrogen, 1.008; nitrogen, 14.01; phosphorus, 31.00; potassium, 39.10; calcium, 40.09. They lead to the following factors for making calculations, and from which the tables were computed:

To compute "phosphoric acid" from phosphorus, multiply by 2.29032.

To compute phosphorus from "phosphoric acid," multiply by 0.43662.

To compute "potash" from potassium, multiply by 1.20460.

To compute potassium from "potash," multiply by 0.830149.

To compute ammonia from nitrogen, multiply by 1.21584.

To compute nitrogen from ammonia, multiply by 0.822472.

To compute lime from calcium, multiply by 1.39910.

To compute calcium from lime, multiply by 0.71474.

All of the tables are used in the same manner and may be illustrated by examples concerning phosphorus and "phosphoric acid."

If a fertilizer is guaranteed to contain 25 per cent of "phosphoric acid," what is its percentage of phosphorus? Look in the columns headed "phosphoric acid" until the number 25 is found; the number opposite, to the left, 10.9156, gives the figures for phosphorus.

If advised to apply 67 pounds of phosphorus to a piece of land, to how much "phosphoric acid" is that equivalent? Look in the columns headed "phosphorus" and find 67; opposite, to the right, the number 153.4514 shows the pounds of "phosphoric acid" that contain 67 pounds of phosphorus.

When the quantities to be reduced are not exactly given in the tables some calculation is necessary. Suppose, for example, that one wished to know the percentage, or the amount, of "phosphoric acid" equivalent to 9.3 of phosphorus. The table does not, unless by chance, show the equivalents except for whole numbers, hence 9.3 is not found in the phosphorus column. However, the figures can be obtained by looking opposite 93, and dividing by 10 the number given there. In this way the "phosphoric acid" corresponding to 9.3 of phosphorus is found to be, in round numbers, 21.3.

Further, suppose one desires to compute the phosphorus in 950 pounds of "phosphoric acid"; 950 is not found in the "phosphoric acid" column, but the desired figures may be found opposite 95, and by moving the decimal point to the right one place, to multiply by 10, we get 414.48 as the amount of phosphorus in 950 of "phosphoric acid."

Again, if it is desired to know the phosphorus equivalent to 756 pounds of "phosphoric acid," one looks in the columns headed "phosphoric acid," and obtains the figures for 700 pounds and 56 pounds separately. These are 305.63 and 24.45. Adding these together, 330.08 is obtained as the amount of phosphorus in 756 of "phosphoric acid."

Once more, if the percentage of "phosphoric acid" in a fertilizer is stated as 23.87, the percentage of phosphorus is found by looking in the table in the "phosphoric acid" columns and getting the phosphorus figures opposite 23 and 87 separately. Those for 87 are then divided by 100 by moving the decimal point two places to the left, thus getting the figures for .87. These are then added to those for 27. Thus, 10.04 + .38 = 10.42, the percentage of phosphorus in a fertilizer containing 23.87 per cent of "phosphoric acid."

These examples should suffice to show the method of using the table for phosphorus and "phosphoric acid,))and precisely the same principles are used with tables X, XI and XII.

TABLE IX. Showing relation between phosphorus and "phosphoric acid" for certain amounts containing equal quantities of phosphorus.

Phosphorus. P	"Phosphoric acid." P_2O_5	Phosphorus. P	"Phosphoric acid." P_2O_5	Phosphorus. P	"Phosphoric acid." P_2O_5	Phosphorus. P	"Phosphoric acid." P_2O_5
0.4366	1.0000	17.0282	39.0000	34.0000	77.8709	65.0000	148.8708
0.8732	2.0000	17.4648	40.0000	34.0564	78.0000	66.0000	151.1611
1.0000	2.2903	17.9014	41.0000	34.4930	79.0000	67.0000	153.4514
1.3099	3.0000	18.0000	41.2258	34.9296	80.0000	68.0000	155.7418
1.7465	4.0000	18.3380	42.0000	35.0000	80.1612	69.0000	158.0321
2.0000	4.5806	18.7747	43.0000	35.3662	81.0000	70.0000	160.3224
2.1831	5.0000	19.0000	43.5161	35.8028	82.0000	71.0000	162.6127
2.6197	6.0000	19.2113	44.0000	36.0000	82.4515	72.0000	164.9030
3.0000	6.8710	19.6479	45.0000	36.2395	83.0000	73.0000	167.1934
3.0563	7.0000	20.0000	45.8064	36.6761	84.0000	74.0000	169.4837
3.4930	8.0000	20.0845	46.0000	37.0000	84.7418	75.0000	171.7740
3.9296	9.0000	20.5211	47.0000	37.1127	85.0000	76.0000	174.0643
4.0000	9.1613	20.9578	48.0000	37.5493	86.0000	77.0000	176.3546
4.3662	10.0000	21.0000	48.0967	37.9859	87.0000	78.0000	178.6450
4.8028	11.0000	21.3944	49.0000	38.0000	87.0322	79.0000	180.9353
5.0000	11.4510	21.8310	50.0000	38.4226	88.0000	80.0000	183.2256
5.2394	12.0000	22.0000	50.3870	38.8592	89.0000	81.0000	185.5159
5.6761	13.0000	22.2676	51.0000	39.0000	89.3225	82.0000	187.8062
6.0000	13.7419	22.7042	52.0000	39.2958	90.0000	83.0000	190.0966
6.1127	14.0000	23.0000	52.6774	39.7324	91.0000	84.0000	192.3869
6.5493	15.0000	23.1409	53.0000	40.0000	91.6128	85.0000	194.6772
6.9859	16.0000	23.5775	54.0000	40.1690	92.0000	86.0000	196.9675
7.0000	16.0322	24.0000	54.9677	40.6057	93.0000	87.0000	199.2578
7.4225	17.0000	24 0141	55.0000	41.0000	93.9031	87.3240	200.0000
7.8592	18.0000	24.4507	56.0000	41.0423	94.0000	88.0000	201.5482
8.0000	18.3226	24.8873	57.0000	41.4789	95.0000	89.0000	203.8385
8.2958	19.0000	25.0000	57.2580	41.9155	96.0000	90.0000	206.1288
8.7324	20.0000	25.3240	58.0000	42.0000	96.1934	91.0000	208.4191
9.0000	20.6129	25.7606	59.0000	42.3521	97.0000	92.0000	210.7094
9.1690	21.0000	26.0000	59.5483	42.7888	98.0000	93.0000	212.9998
9.6056	22.0000	26.1972	60.0000	43.0000	98.4838	94.0000	215.2900
10.0000	22.9032	26.6338	61.0000	43.2254	99.0000	95.0000	217.5804
10.0423	23.0000	27.0000	61.8386	43.6620	100.0000	96.0000	219.8707
10.4789	24.0000	27.0704	62.0000	44.0000	100.7741	97.0000	222.1610
10.9156	25.0000	27.5071	63.0000	45.0000	103.0644	98.0000	224.4514
11.0000	25.1936	27.9437	64.0000	46.0000	105.3547	99.0000	226.7417
11.3521	26.0000	28.0000	64.1290	47.0000	107.6450	100.0000	229.0820
11.7887	27.0000	28.3803	65.0000	48.0000	109.9354	130.9860	300.0000
12.0000	27.4838	28.8169	66.0000	49.0000	112.2257	174.6480	400.0000
12.2254	28.0000	29.0000	66.4193	50.0000	114.5160	200.0000	458.0640
12.6620	29.0000	29.2535	67.0000	51.0000	116.8063	218.3100	500.0000
13.0000	29.7742	29.6902	68.0000	52.0000	119.0964	261.9720	600.0000
13.0986	30 0000	30.0000	68.7096	53.0000	121.3870	300.0000	687.0960
13.5352	31.0000	30.1268	69.0000	54.0000	123.6773	305.6340	700.0000
13.9718	32.0000	30.5634	70.0000	55.0000	125.9676	349.2960	800.0000
14.0000	32.0645	31.0000	71.0000	56.0000	128.2579	392.9580	900.0000
14.4085	33.0000	31.4366	72.0000	57.0000	130.5482	400.0000	916.1280
14.8451	34.0000	31.8733	73.0000	58.0000	132.8386	436.6200	1000 0000
15.0000	34.3548	32.0000	73.2902	59.0000	135.1259	500.0000	1145.1600
15.2817	35.0000	32.3099	74.0000	60.0000	137.4192	600.0000	1374.1920
15.7183	36.0000	32.7465	75.0000	61.0000	139.7100	700.0000	1603.2240
16.0000	36.6451	33.0000	75.5806	62.0000	141.9998	800.0000	1832.2560
16.1549	37.0000	33.1831	76.0000	63.0000	144.2902	900.0000	2061.2880
16.5916	38.0000	33.6197	77.0000	64.0000	146.5805	1000.0000	2290.3200
17.0000	38.9354	....	....	....	....	....	....

TABLE X. Showing relations between potassium and "potash" for certain amounts containing equal quantities of potassium.

Potassium. K	"Potash." K_2O	Potassium. K	"Potash." K_2O	Potassium. K	"Potash." K_2O	Potassium. K	"Potash." K_2O
0.8301	1.0000	25.7346	31.0000	50.6391	61.0000	75.0000	90.3450
1.0000	1.2046	26.0000	31.3196	51.0000	61.4346	75.5436	91.0000
1.6603	2.0000	26.5648	32.0000	51.4692	62.0000	76.0000	91.5496
2.0000	2.4092	27,0000	32.5242	52.0000	62.6392	76.3737	92.0000
2.4904	3.0000	27.3949	33.0000	52.2994	63.0000	77.0000	92.7542
3.0000	3.6138	28.0000	33.7288	53.0000	63.8438	77.2039	93.0000
3.3206	4.0000	28.2251	34.0000	53.1295	64.0000	78.0000	93.9588
4.0000	4.8184	29.0000	34.9334	53.9597	65.0000	78.0340	94.0000
4.1507	5.0000	29.0552	35.0000	54.0000	65.0484	78.8642	95.0000
4.9809	6.0000	29.8854	36.0000	54.7898	66.0000	79.0000	95.1634
5.0000	6.0230	30.0000	36.1380	55.0000	66.2530	79.6943	96.0000
5.8110	7.0000	30.7155	37.0000	55.6200	67.0000	80.0000	96.3680
6.0000	7.2276	31.0000	37.3426	56.0000	67.4576	80.5245	97.0000
6.6412	8.0000	31.5457	38.0000	56.4501	68.0000	81.0000	97.5726
7.0000	8.4322	32.0000	38.5472	57 0000	68.6622	81.3546	98.0000
7.4713	9 0000	32.3758	39.0000	57.2803	69.0000	82.0000	98.7772
8.0000	9.6368	33.0000	39.7518	58.0000	69.8668	82.1848	99.0000
8.3015	10.0000	33.2060	40.0000	58.1104	70.0000	83.0000	99.9818
9.0000	10.8414	34.0000	40.9564	58.9406	71.0000	83.0149	100.0000
9.1316	11.0000	34.0361	41.0000	59.0000	71.0714	84.0000	101.1864
9.9618	12.0000	34.8663	42.0000	59.7707	72.0000	85.0000	102.3910
10.0000	12.0460	35.0000	42.1610	60.0000	72.2760	86.0000	103.5956
10.7920	13.0000	35.6964	43.0000	60.6009	73.0000	87.0000	104.8002
11.0000	13.2506	36.0000	43.3656	61.0000	73.4806	88.0000	106.0048
11.6221	14.0000	36.5266	44.0000	61.4310	74.0000	89.0000	107.2094
12.0000	14.4552	37.0000	44.5702	62.0000	74.6852	90.0000	108 4140
12.4525	15,0000	37.3567	45.0000	62.2612	75.0000	91.0000	109.6186
13.0000	15,6598	38.0000	45.7748	63.0000	75.8898	92.0000	110.8232
13.2824	16.0000	38.1869	46.0000	63.0913	76.0000	93.0000	112.0278
14.0000	16.8644	39.0000	46.9794	63.9215	77.0000	94.0000	113.2324
14.1125	17.0000	39.0170	47.0000	64.0000	77.0944	95.0000	114.4370
14.9427	18.0000	39.8472	48.0000	64.7516	78.0000	96.0000	115.6416
15.0000	18.0690	40.0000	48.1840	65.0000	78.2990	97.0000	116.8462
15.7728	19.0000	40.6773	49.0000	65.5818	79.0000	98.0000	118.0508
16.0000	19.2736	41.0000	49.3886	66.0000	79.5036	99.0000	119.2554
16.6030	20.0000	41.5075	50.0000	66.4119	80.0000	100.0000	120.4600
17.0000	20.4782	42.0000	50.5932	67.0000	80.7082	166.0298	200.0000
17.4331	21.0000	42.3376	51.0000	67.2421	81.0000	200.0000	240.9200
18.0000	21.6828	43.0000	51.7978	68.0000	81.9128	249.0447	300.0000
18.2633	22.0000	43.1677	52.0000	68.0722	82.0000	300.0000	361.3800
19.0000	22.8874	43.9979	53.0000	68.9024	83.0000	332.0596	400.0000
19.0934	23.0000	44.0000	53.0024	69.0000	83.1174	400.0000	481 0000
19.9236	24.0000	44.8280	54.0000	69.7325	84.0000	415.0745	500.0000
20.0000	24.0920	45.0000	54.2070	70.0000	84.3220	498.0894	600.0000
20.7537	25.0000	45.6582	55.0000	70.5627	85.0000	500.0000	602.3000
21.0000	25.2966	46.0000	55.4116	71.0000	85.5266	581.1043	700.0000
21.5839	26.0000	46 4883	56.0000	71.3928	86.0000	600.0000	722.7600
22.0000	26.5012	47.0000	56.6162	72.0000	86.7312	664.1192	800.0000
22.4140	27.0000	47.3185	57.0000	72.2230	87.0000	700.0000	843.2200
23.0000	27.7058	48.0000	57.8208	73.0000	87.9358	747.1341	900.0000
23.2442	28.0000	48.1486	58.0000	73.0531	88.0000	800.0000	963.6800
24.0000	28.9104	48.9788	59.0000	73.8833	89 0000	830.0000	1000.0000
24.0743	29.0000	49.0000	59.0254	74.0000	89.1404	900.0000	1084.1400
24.9045	30.0000	49.8089	60.0000	74.7134	90.0000	1000.0000	1204.6000
25.0000	30.1150	50.0000	60.2300				

TABLE XI. Showing relation between nitrogen and ammonia for certain amounts containing equal quantities of nitrogen.

Nitrogen. N	Ammonia. NH_3	Nitrogen. N	Ammonia. NH_3	Nitrogen. N	Ammonia. NH_3	Nitrogen. N	Ammonia. NH_3
0.8225	1.0000	25.4966	31.0000	50.1708	61.0000	74.8450	90.0000
1.0000	1.2158	26.0000	31.6118	50.9933	62.0000	75.0000	91.1880
1.6449	2.0000	26.3191	32.0000	51.0000	62.0078	75.6674	92.0000
2.0000	2.4317	27.0000	32.8277	51.8157	63.0000	76.0000	92.4038
2.4674	3.0000	27.1416	33.0000	52.0000	63.2237	76.4899	93.0000
3.0000	3.6475	27.9640	34.0000	52.6382	64.0000	77.0000	93.6197
3.2899	4.0000	28.0000	34.0435	53.0000	64.4395	77.3124	94.0000
4.0000	4.8634	28.7865	35.0000	53.4607	65.0000	78.0000	94.8355
4.1124	5.0000	29.0000	35.2594	54.0000	65.6534	78.1348	95.0000
4.9348	6.0000	29.6090	36.0000	54.2832	66.0000	78.9573	96.0000
5.0000	6.0792	30.0000	36.4752	55.0000	66.8712	79.0000	96.0514
5.7573	7.0000	30.4315	37.0000	55.1056	67.0000	79.7798	97.0000
6.0000	7.2950	31.0000	37.6910	55.9280	68.0000	80.0000	97.2672
6.5798	8.0000	31.2539	38.0000	56.0000	68.0870	80.6023	98.0000
7.0000	8.5109	32.0000	38.9069	56.7506	69.0000	81.0000	98.4836
7.4022	9.0000	32.0764	39.0000	57.0000	69.3029	81.4247	99.0000
8.0000	9.7267	32.8989	40.0000	57.5730	70.0000	82.0000	99.6989
8.2247	10.0000	33.0000	40.1227	58.0000	70.5187	82.2472	100.0000
9.0000	10.9426	33.7214	41.0000	58.3955	71.0000	83.0000	100.9147
9.0472	11.0000	34.0000	41.3386	59.0000	71.7346	84.0000	102.1306
9.8697	12.0000	34.5438	42.0000	59.2180	72.0000	85.0000	103.3464
10.0000	12.1584	35.0000	42.5544	60.0000	72.9504	86.0000	104.5622
10.6921	13.0000	35.3663	43.0000	60.0405	73.0000	87.0000	105.7781
11.0000	13.3742	36.0000	43.7702	60.8629	74.0000	88.0000	106.9939
11.5146	14.0000	36.1888	44.0000	61.0000	74.1662	89.0000	108.2098
12.0000	14.5900	37.0000	44.9861	61.6854	75.0000	90.0000	109.4256
12.3371	15.0000	37.0112	45.0000	62.0000	75.3821	91.0000	110.6414
13.0000	15.8059	37.8337	46.0000	62.5079	76.0000	92.0000	111.8573
13.1596	16.0000	38.0000	46.2019	63.0000	76.5979	93.0000	113.0731
13.9820	17.0000	38.6562	47.0000	63.3303	77.0000	94.0000	114.2890
14.0000	17.0218	39.0000	47.4178	64.0000	77.8138	95.0000	115.5048
14.8045	18.0000	39.4787	48.0000	64.1528	78.0000	96.0000	116.7206
15.0000	18.2376	40.0000	48.6336	64.9753	79.0000	97.0000	117.5365
15.6270	19.0000	40.3011	49.0000	65.0000	79.0296	98.0000	119.1523
16.0000	19.4534	41.0000	49.8494	65.7978	80.0000	99.0000	120.3682
16.4494	20.0000	41.1236	50.0000	66.0000	80.2454	100.0000	121.5840
17.0000	20.6693	41.9461	51.0000	66.6202	81.0000	164.4944	200.0000
17.2719	21.0000	42.0000	51.0653	67.0000	81.4613	200.0000	243.1680
18.0000	21.8851	42.7685	52.0000	67.4427	82.0000	246.7416	300.0000
18.0944	22.0000	43.0000	52.2811	68.0000	82.6771	300.0000	364.7520
18.9169	23.0000	43.5910	53.0000	68.2652	83.0000	328.9880	400.0000
19.0000	23.1010	44.0000	53.4970	69.0000	83.8930	400.0000	486.3360
19.7393	24.0000	44.4135	54.0000	69.0876	84.0000	411.2360	500.0000
20.0000	24.3168	45.0000	54.7128	69.9101	85.0000	493.4832	600.0000
20.5618	25.0000	45.2360	55.0000	70.0000	85.1088	500.0000	607.9200
21.0000	25.5326	46.0000	55.9286	70.7326	86.0000	575.7304	700.0000
21.3843	26.0000	46.0584	56.0000	71.0000	86.3246	600.0000	729.5040
22.0000	26.7485	46.8809	57.0000	71.5551	87.0000	657.9776	800.0000
22.2067	27.0000	47.0000	57.1445	72.0000	87.5405	700.0000	851.0880
23.0000	27.9643	47.7034	58.0000	72.3775	88.0000	740.2248	900.0000
23.0292	28.0000	48.0000	58.3603	73.0000	88.7563	800.0000	972.6720
23.8517	29.0000	48.5258	59.0000	73.2000	89.0000	822.4720	1000.0000
24.0000	29.1802	49.0000	59.5762	74.0000	89.9722	900.0000	1094.2560
24.6742	30.0000	49.3483	60.0000	74.0225	90.0000	1000.0000	1215.8400
25.0000	30.3960	50.0000	60.7920				

TABLE XII. Showing relation between calcium and lime for certain amounts containing equal quantities of calcium.

Calcium. Ca	Lime. CaO	Calcium Ca	Lime. CaO	Calcium. Ca	Lime. CaO	Calcium. Ca	Lime. CaO
0.7147	1.0000	28.5864	33.0000	46.4581	65.0000	69.3298	97.0000
1.0000	1.3991	24.0000	33.5784	47.0000	65.7577	70.0000	97.9370
1.4295	2.0000	24.3012	34.0000	47.1728	66.0000	70.0445	98.0000
2.0000	2.7982	25.0000	34.9775	47.8876	67.0000	70.7593	99.0000
2.1442	3.0000	25.0159	35.0000	48.0000	67.1568	71.0000	99.3361
2.8590	4.0000	25.7306	36.0000	48.6023	68.0000	71.4740	100.0000
3.0000	4.1973	26.0000	36.3766	49.0000	68.5559	72.0000	100.7352
3.5737	5.0000	26.4454	37.0000	49.3171	69.0000	73.0000	102.1343
4.0000	5.5964	27.0000	37.7757	50.0000	69.9550	74.0000	103.5334
4.2884	6.0000	27.1601	38.0000	50.0318	70.0000	75.0000	104.9325
5.0000	6.9955	27.8749	39.0000	50.7465	71.0000	76.0000	106.3316
5.0032	7.0000	28.0000	39.1748	51.0000	71.3541	77.0000	107.7307
5.7179	8.0000	28.5896	40.0000	51.4613	72.0000	78.0000	109.1298
6.0000	8.3946	29.0000	40.5739	52.0000	72.7532	79.0000	110.5289
6.4327	9.0000	29.3043	41.0000	52.1760	73.0000	80.0000	111.9280
7.0000	9.7937	30.0000	41.9730	52.8908	74.0000	81.0000	113.3271
7.1474	10.0000	30.0191	42.0000	53.0000	74.1523	82.0000	114.7262
7.8621	11.0000	30.7338	43.0000	53.6055	75.0000	83.0000	116.1253
8.0000	11.1928	31.0000	43.3721	54.0000	75.5514	84.0000	117.5244
8.5769	12.0000	31.4486	44.0000	54.3202	76.0000	85.0000	118.9235
9.0000	12.5919	32.0000	44.7712	55.0000	76.9505	86.0000	120.3226
9.2916	13.0000	32.1633	45.0000	55.0350	77.0000	87.0000	121.7217
10.0000	13.9910	32.8780	46.0000	55.7497	78.0000	88.0000	123.1208
10.0064	14.0000	33.0000	46.1703	56.0000	78.3496	89.0000	124.5199
10.7211	15.0000	33.5928	47.0000	56.4645	79.0000	90.0000	125.9190
11.0000	15.3901	34.0000	47.5694	57.0000	79.7487	91.0000	127.3181
11.4358	16.0000	34.3075	48.0000	57.1792	80.0000	92.0000	128.7172
12.0000	16.7892	35.0000	48.9685	57.8939	81.0000	93.0000	130.1163
12.1506	17.0000	35.0223	49.0000	58.0000	81.1478	94.0000	131.5154
12.8653	18.0000	35.7370	50.0000	58.6087	82.0000	95.0000	132.9145
13.0000	18.1883	36.0000	50.3676	59.0000	82.5469	96.0000	134.3136
13.5801	19,0000	36.4517	51.0000	59.3234	83.0000	97.0000	135.7127
14.0000	19.5874	37.0000	51.7667	60.0000	83.9460	98.0000	137.1118
14.2948	20.0000	37.1665	52.0000	60.0382	84.0000	99.0000	138.5109
15.0000	20.9865	37.8812	53.0000	60.7529	85.0000	100.0000	139.9100
15.0095	21.0000	38.0000	53.1658	61.0000	85.3451	142.9480	200.0000
15.7243	22.0000	38.5960	54.0000	61.4676	86.0000	200.0000	279.8200
16.0000	22.3856	39.0000	54.5649	62.0000	86.7442	214.4220	300.0000
16.4390	23.0000	39.3107	55.0000	62.1824	87.0000	285.8960	400.0000
17.0000	23.7847	40.0000	55.9640	62.8971	88.0000	300.0000	419.7300
17.1538	24.0000	40.0254	56.0000	63.0000	88.1433	357.3700	500.0000
17.8685	25.0000	40.7402	57.0000	63.6119	89.0000	400.0000	559.6400
18.0000	25.1838	41.0000	57.3631	64.0000	89.5424	428.8440	600.0000
18.5832	26.0000	41.4549	58.0000	64.3266	90.0000	500.0000	699.5500
19.0000	26.5829	42.0000	58.7622	65.0000	90.4515	500.3180	700.0000
19.2980	27.0000	42.1697	59.0000	65.0413	91.0000	571.7920	800.0000
20.0000	27.9820	42.8844	69.0000	65.7561	92.0000	600.0000	839.4600
20.0127	28.0000	43.0000	60.1613	66.0000	92.3406	643.2660	900.0000
20.7275	29.0000	43.5991	61.0000	66.4708	93.0000	700.0000	979.3700
21.0000	29.3811	44.0000	61.5604	67.0000	93.7397	714.7400	1000.0000
21.4422	30.0000	44.3139	62.0000	67.1856	94.0000	800.0000	1119.2800
22.0000	30.7802	45.0000	62.9595	67.9003	95.0000	900.0000	1259.1900
22.1569	31.0000	45.0286	63.0000	68.0000	95.1388	1000.0000	1399.1000
22.8717	32.0000	45.7434	64.0000	68.6150	96.0000		
23.0000	32.1793	46.0000	64.3586	69.0000	96.5379		