acted upon by the organic matter and carbonic acid, which comes into contact with them in the soil when they are used in the raw state as manure, and it is found that unless ground to an impalpable powder, the solubility is not sufficient to supply the requirements of a growing crop.

To Liebig is due the credit of first devising a means of converting the insoluble phosphate of bone into a soluble and readily available form, and the process was subsequently adopted for mineral phosphate by Lawes. This consists in treating the finely ground mineral phosphate with sulphuric acid, by which means the tribasic phosphate of lime is converted into monobasic phosphate of lime and gypsum, both of which are soluble in water. It is this substance, known in commerce as superphosphate of lime, which forms the basis of the great majority of artificial manures found in the market.

It will, therefore, be my endeavour to place before you the principles on which the manufacture of superphosphate is based and the methods by which it is accomplished, and afterwards to sketch the way in which the various manures are compounded from it. The capital invested in the manufacture of superphosphate and manures is enormous, and the industry is of such great commercial importance, that it is not to be wondered at that many forms of apparatus and modifications of processes have from time to time been devised to effect this object, but I shall restrict myself to the methods generally practised, without attempting to cover the whole ground. With this end in view I shall describe the processes followed in one of the largest and most modern of our manure works, and endeavour, as I proceed, to describe the principles which should regulate the successful working of the processes.

In all large manure works the manufacture of sulphuric acid is carried on, and for this purpose large chamber capacity has often to be provided. The purity of the acid is immaterial, and pyrites is, therefore, almost invariably used as the source of the sulphur. The methods by which the acid is formed are so well known, and have been described in so many books, that any description from me would be out of place, more especially as the manufacture of it is only a means to an end and not an essential part of the manufacture of manure properly so-called.

The mineral phosphate, if in the rock state, is first reduced in a Blake's crusher to a moderately fine condition. This reduction is brought about by a biting action of the machine, which answers its purpose admirably. Any other form of crusher which will reduce the rock to a sufficiently fine condition for the mill stones, through which it has next to be passed, may be used.

The phosphate is then ground between mill-stones until it will pass through sieves of forty meshes to an inch. The process so far, is entirely mechanical, and presents no difficulties to those accustomed to the use of such machinery, but the proper conducting of this part of the operation is of the utmost importance in successful working. A glance at the chemistry of the next operation will make this apparent. To convert the insoluble monocalcic phosphate, it is treated with sulphuric acid of about 1·55 specific gravity. The changes which take place are represented by the following equation:—

$$Ca_2 P_2 O_8 + 2(H_2 SO_4 + 2 H_2 O) =$$
$$Ca H_4 P_2 O_8 + 2(Ca SO_4 2 H_2 O).$$

This, doubtless, is only generally true, as on the manufacturing scale the decomposition is not absolutely complete, and other reactions in a minor degree take place; but the reaction given above is the one which should be aimed at by the manufacturers. But if the raw phosphate has not been ground sufficiently fine it must be evident that, as the acid is only used to conform with the equation given, the sulphuric acid will be diminished in quantity as the reaction proceeds, and the inner portions of the larger pieces of rock will remain unattacked, and consequently the process will be only partially complete, and a part of the phosphate will remain in an insoluble condition to the proportionate detriment of the manure. One of the great secrets of success is, therefore, to grind finely, and the finer the better.

The addition of the acid to the finely ground phosphate is made in what is known as a "horizontal mixer." The acid is contained in a tank with a gauge attached to it for the purpose of measurement, and is allowed to run into the mixer by removing a plug, and is then intimately mixed with the raw phosphates by means of revolving blades. The mixer is slightly inclined to admit of the mixture, which, directly after mixing, is fluid, being run off, when a plug, placed at the lower end for this purpose, is removed. The chemical action which takes place on the addition of the acid causes the temperature to rise very considerably, and it is, therefore, allowed to run into a reservoir placed below, which is technically called a "den," for the purpose of settling and cooling. A good sized "den" will hold forty tons, and may be filled in a day. After the superphosphate has been allowed to remain for a day it will have set and may be dug out and stored for further use. When properly manufactured superphosphate should be in a dry and almost friable condition, as, if at all wet or lumpy, it makes the process of sowing both difficult and unsatisfactory.

The proportions in which the acid and raw phosphate are mixed will depend upon the nature and composition of the phosphate and upon the strength of acid. The most convenient strength of the latter for ordinary purposes is 110° T (1·55 specific gravity).

None of the phosphatic materials are pure, or approximately pure tricalcic phosphate, and consideration has, therefore, to be taken of the action of the sulphuric acid upon these extraneous substances. The principal of these, for matters of calculation, is carbonate of lime. This will be acted upon before the acid attacks the phosphate, but its presence in raw phosphate in moderate proportions is by no means an unmixed evil, as the liberated carbonic acid tends to assist the intimate mixing of the materials, and the gypsum formed by the reaction helps to dry the manure. In large quantities it is prejudicial and renders certain phosphates practically useless except for mixing with other materials which contain but little or no carbonate of lime. The following table shows the quantities of acid of 100° T which are required by 100 parts of the given substances:—

100 parts require	Sulphuric Acid 110° F.
Tricalcic Phosphate	100
Calcic Carbonate	156
Ferric Oxide	97
Alumina	151
Calcic Fluoride	200

In practice, however, it is advisable to use a somewhat greater quantity of acid than is indicated in this table. In the majority of cases equal proportions of sulphuric acid and phosphate are found to yield satisfactory results.

Large quantities of superphosphate are sold without any further mixing, the farmer using his own judgement as to what he should apply with it. This is undoubtedly a good plan when there is the requisite knowledge, but it requires an amount of skill which is possessed by only a comparatively few of our agriculturists, and it is, therefore, better for the manufacturer to send out a prepared manure. When, however, the superphosphate is sold as such it should not be bagged until wanted, as it apt to cake and to destroy the bags.

From the description which I have already given of the various kinds of plant food it will be evident that superphosphate is valuable only on account of the soluble phosphate which it contains, the other constituents being of practically little value on the majority of soils. It is customary, therefore, to sell it on the basis of the "soluble phosphate" which it yields. This term has no strictly scientific meaning, but represents the quantity of tribasic phosphate of lime which would have to be rendered soluble in order to yield the quantity stated. So long as the custom is universal it is as convenient as any other basis and fairly represents the true value of the manure. Before leaving the manufacture of superphosphate it is necessary to point out some of the conditions which affect the stability of the compound. It has been long known that certain manures after having been kept for some time yield a less percentage of soluble phosphate than when first manufactured. This is what is technically known as "going back," and the phosphates are said to be "reverted" or "precipitated." The principal cause of this deterioration is undoubtedly the presence of oxide of iron and alumina in the raw material from which the superphosphate is manufactured. The phosphate of iron and alumina which are first formed react after a time upon the monocalcic phosphate and form calcic sulphate and ferric and aluminic phosphate, substances insoluble in water. It is, therefore, advisable in the choice of a raw material to obtain one which is as free as possible from oxide of iron and alumina.

It has been argued, however, by some interested in the matter that these precipitated phosphates are as valuable as the soluble phosphate, and that the manufacturer ought, therefore, to be paid for the phosphates which have been precipitated in the manure on the same basis at which the soluble phosphate