charcoal. By means of wide tubes of plate iron or copper, the acid and oil which would otherwise be dissipated in the air are collected; the watery acid part being then separated from the other is evaporated to dryness, and the residuum by calcination affords an ash extremely rich in alkali.

Potash is converted into a much purer alkaline salt called pearl ash, by calcination; for this purpose the potash broken into moderately small pieces, is spread on the floor of a reverberatory furnace, and being then kept red hot, but not melted, for an hour or two, stirring it occasionally with an iron rake, all the carbonaceous and coloring particles are burned out, and there remains behind a dry, porous, and considerably caustic salt extremely deliquescent, and from its bluish-white color called pearl ash.

The uses of potash are innumerable. It is consumed in large quantities by the glass maker, soapboiler, and bleacher, and in the laboratory it is in constant and indispensable service.—*Glassware Reporter*.

LINSEED—ITS BOTANY AND CHEMISTRY.*

By E. H. EARLE.

THE plant known from the value of its products in manufactures and the arts as *Linum usitatissimum* is an upright annual having a height of from one to two feet. The stem is smooth and green, and the leaves are linear lanceolate, alternate, and sessile. The calyx consists of five sepals, which are ovate and acute, and have membranous margins. The corolla consists of five petals, which are of much larger size than the sepals. They are somewhat crenated and are caducous. These petals are of a conspicuous purplish blue color. Both stamens and styles are five in number. The fruit is a capsule, which dehisces septically; the carpels being divided from each other, and these again partially divided down the partition between each pair of seeds.

The native country of the flax plant is unknown, but central Asia has been mentioned as the probable source.

The plant is reared in this country in Lincolnshire, Cambridge, Suffolk, Devon, and Somersetshire. The seeds obtained from the two latter counties are held in highest esteem. In India the flax plant has been under cultivation for centuries for the seeds, whereas in Europe the fiber of the plant was more developed, as linen and not oil was desired.

Experiments have lately been made in India with Dutch and American seed, with a view to cultivating a good flax-yielding plant, but they have not as yet been very successful. This is said to be owing to insufficient moisture in the soil. The seeds are sown in the autumn. India also imports much European grown seed for the extraction of the oil, which possesses more satisfactory drying properties than that obtained from native grown seed. At least such is stated to be the case.

Flax being the more important of the products of this plant, I will allude to it first.

Flax has been known from the earliest ages. It constituted a field crop at the period when the Israelites were in Egypt, and the fibers were used for the manufacture of garments. Herodotus mentions this fabric as constituting articles of clothing among the Egyptians, upon whose monuments and tombs the processes which the fiber underwent for economic purposes are depicted with great accuracy. The clothes in which the mummies are wrapped are found to consist of linen, but of a very coarse texture. It was also used for filtering wine through, and a very rough or strong quality formed sails for boats, according to classical writers.

The Romans seemed to prefer wool to linen in the way of clothing. The emperor Alexander Severus is reported to have been the first Roman who had the courage to wear a linen shirt. After the fall of the Roman Empire flax-weaving was lost sight of until the tenth century, when it was started at Ypres in Flanders, and was from that time carried on in various parts of the Continent with varying success. I believe the celebrated Bayeux tapestry is worked on linen.

The seeds from which the flax plant is to be reared should be plump, heavy, and shining; and should be freed from impurities by sifting.

The soil answering best for its cultivation is a dry loam, and in good flax-growing soils silica is found to the amount of 60 per cent. or, in some cases, 80 per cent. Flax has always been notorious for exhausting in a high degree the soil from which it is raised. In the *Georgics*, Virgil speaks of it as "scorching the fields." This was owing in a great measure to the cultivators not understanding the rotation of crops. Thus many districts are barren in Sicily and Asia Minor—once the granary of Rome—Spain, and the Campania, which were historically fruitful.

Irish-grown flax is considered the best for the manufacture of linen, and there the crops are rotated so as to allow of an interval of about six years before again using the soil for flax. The first year grass is grown; in the second year oats; in the third year potatoes or turnips; in the fourth year wheat; in the fifth year flax, clover, or beans. In this way the soil suffers no harm.

In order to obtain a superior fiber for linen manufacture, the plant is gathered before it reaches maturity, which is indicated by the partial change of the green stem to yellow, and of the green capsule to brown.

The stem consists essentially of a woody interior, and externally of the fiber needed for flax.

The plant is gathered and dragged through a rough comb, which separates the capsules. This is known as "ripping" it. It is next "retted," which operation consists in steeping it in soft water for about a fortnight, in order to dissolve out the gummy and resinous matters holding the woody and fibrous portions together. Ponds have to be dug out for the purpose of steeping the flax, as the plant renders the water so offensive that cattle drinking at a river or stream in which the operation had been conducted would be poisoned. In the reign of King Henry VIII. an act was passed forbidding the pollution of river water by such means.

In Sweden the plant is boiled in sea water, together with lime and birchwood ashes, and finally washed with soap. This operation ended, it is "grassed," or laid out for sun bleaching, being turned once or twice in order that all parts may experience the same influence. This occupies about a fortnight. It is then tied in sheaves or bundles and sun dried. It is often broken or "scutched" before being sent into the market. This process consists in beating with mallets or flails until the adhering wooden portion is well broken up. This is now chiefly done by machinery. It undergoes in the mills many processes which are too intricate to be followed out in a paper of this nature, besides involving some technical education. After being "combed" or "heckled" in the mill in order to separate the fibers, flax presents long glistening silver gray or yellowish fibers re-

sembling silk when viewed from a short distance. The fibers broken off short in combing constitute tow.

Flax is also imported from the Baltic ports, Holland, and Belgium.

Scraped linen constitutes lint. There has been some discussion from time to time as to the superiority of lint over cotton in bandages. Cotton is more irritating, and this is said to be due to the cells, of which it is composed, being flat and having sharp edges, or by these flat cells twisting when wetted, in both cases proving uncomfortable to the patient. Flax cells, however, are cylindrical, and thus, having no sharp edges, are superior for dressings.

The seeds now come under our notice. They are small, brown, and glistening; oval in shape and having sharp edges. They are official, being used for the infusion of linseed. They are used for food in some parts of Russia and Abyssinia.

The seed coats contain a mucilage, according to some writers, which exists in the growing plant as starch. The nucleus contains much fixed oil (about one-third the weight of the seed). It is when first expressed of a pale color, but darkens on keeping. It consists chiefly of glycerides, together with fatty acids—notably, linoleic—to which the drying properties are due.

The seeds are obtained from St. Petersburg, Riga, Libau, and other Baltic ports both in Russia and Germany, the Black Sea ports, Bombay, Calcutta, Italy, New York, and La Plata in South America. The Baltic supplies the greatest amount, and the La Plata seeds go chiefly to the Continent.

Linseed meal is officially directed to be obtained by powdering the cake from which the oil has been expressed. It is used as a poultice, which is often stated to have irritating instead of soothing effects. This may be due to the admixture of cruciferous seeds, such as rape and mustard. As the irritation was supposed to arise from the natural oil of the linseed becoming rancid, the meal is directed to be obtained—as stated before—from the cake and not from the seeds. Olive oil is directed to be added when a poultice is required in order to replace the natural oil, which to say the least is an inconvenient arrangement.

Taking now the expression of the oil from the seeds as actually carried on: The seeds are stored by means of an elevator at the top of the warehouse, and by means of a long wooden tube a stream of this seed is poured into a large wooden box, which allows a regulated amount to pass in a continual stream between two almost solid steel rollers about 18 inches in diameter, and on emerging from between these the seed falls upon a sloping iron ledge which directs the stream between two more rollers, and so on, until by a course shifting from one side to the other, the seeds emerge finely ground, and constituting a true linseed meal.

The temperature of the room is about 90°, so that a more plentiful supply of oil should be yielded.

Machinery now carries the meal into a large tub-like arrangement known as the "kettle." A workman below waits with iron trays upon which are coarse cloths. These trays are about a yard long and a foot wide.

These trays are placed below the "kettle," from which, by means of a trap, a requisite amount of meal is deposited upon the cloth-covered tray. The meal is pressed just sufficiently to cause it to adhere together, and it is then covered at the top by the ends of the cloth before mentioned, and the tray is then placed in a press by another workman, who accumulates a pile of about a dozen in a press in about ten minutes.

At the bottom of this pile of trays is a solid steel slab, which now ascends and presses the cakes against the top of the press. The oil flows very freely into tanks below, which have only one small hole for the oil to run out of. This prevents a too rapid current, which would carry mucilage and other matter along with the oil, which runs through a series of tanks, always depositing until it reaches the large storage tanks, from which casks are filled for sale or export.

The press being loosened again, the trays are removed, and the cake, now apparently quite dry, is divested of the cloth which was used to allow of the cake being more easily removed from the trays, and the edges neatly beveled by means of a sharp knife running in a groove, which cuts the cake to the required shape and size.

The portions of cake trimmed off are ground up and worked over again.

These cakes weigh about 12 pounds and contain mucilage, phosphates, and nitrogenous matter, and about 4 per cent. of oil, which renders them of great service in cattle feeding.

The seeds I saw worked were Calcutta seeds, and appeared remarkably free from admixture. Thirty-three per cent. of oil was extracted and 4 per cent. left in the cake, so these seeds yielded very good results.

Linseed oil may be divided into four kinds—raw, refined, boiled, and artist's.

Raw oil is obtained in the manner just described.

Refined oil is raw oil allowed to stand for weeks or even months, to allow impurities to settle, and then is treated with litharge or acetate of lead either when hot or cold. It is also sometimes heated with sulphate of zinc or alum, which is said to hasten the deposit of impurities. The lead is often separated with oil of vitriol, and this bleaches the oil and also converts any lead into sulphate, which might, when mixed with paint as white lead, be converted otherwise into yellow oxide when exposed to air.

Boiled Oil.—Here the oil is boiled for about five hours, and then driers are gradually added in the proportion of 5 pounds to a ton of oil. The whole is then boiled for an hour. After this the oil is left by some manufacturers until a pellicle forms, when the oil is then run off or ladled out. Some manufacturers allow it to stand for weeks until all the driers have settled and the oil is clear and bright. The sediment and scum are used in putty. It is tested by dipping sized paper into the oil and seeing if a varnish is formed, on drying, over the whole of the paper. If only the bottom of the paper is varnished, while the top remains greasy, the oil is insufficiently boiled. The drying into a resin or varnish is seen to be due to the absorption from the air by oxygen, by spreading the oil over zinc plates and weighing. When a varnish is formed, the weight of the oil is found to have increased by nearly one-half.

Boiling oil was almost a traditional arrangement for promoting its drying; but black oxide of manganese and red lead were added with the idea of giving to the oil at a high temperature that amount of oxygen requisite to aid its commencement in absorbing oxygen from the air. The black oxide is said to part with oxygen, which it again absorbs on being stirred to the surface, over which a current of air is passing. Borate of manganese is also used. The pans in which the boiling takes place are of copper or iron, with an iron jacket, and are heated by steam. They have a dome cover from which two fans or stirrers are arranged to stir up the oil. From the dome the irritating vapors of acrolein are conducted into bottles of water.

Lastly comes artist's oil. There are several kinds, which are made to suit private forms, and consist chiefly of heating the oil with acetate of lead and litharge, and bleaching with ferrous sulphate or by exposure to sunlight.

The foregoing paper was followed by one on—

THE CHEMISTRY OF LINSEED.

By EDW. CULLINAN, JR.

THE chemistry connected with linseed and its products is not only very interesting, but has received some very important technical applications.

Composition of the Seeds.—The testa contains an abundant secretion of mucilage; the cotyledons, a fixed oil. The average composition of linseed, as analyzed by Dr. T. Anderson, shows the following results:

Albuminous substances.....	24.24	} parts in 100.
Oil.....	34.00	
Gum, sugar, and cellulose.....	30.73	
Ash.....	3.33	
Water.....	7.50	

A more complete analysis of the seeds by Meyer gave the following results:

Fat oil.....	11.265	} parts in 100.
Wax oil.....	0.146	
Acrid soft resin.....	2.488	
Resinous coloring matter.....	0.550	
Yellow extractive and tannin.....	1.917	
Sweet extractive, malic acid, and salts.....	10.884	} parts in 100.
Gum.....	6.154	
Nitrogenous mucilage, acetic acid, and salts.....	15.120	
Starch.....	1.480	
Albumen.....	2.782	
Gluten.....	2.932	} parts in 100.
Husk.....	44.382	

The seeds are principally cultivated for the oil, but linseed cake, *i. e.*, the marc left after the expression of the oil, is also a valuable substance for feeding cattle. According to Voelcker's analysis,* it contains:

Oil.....	10.90	} parts in 100.
Albuminous substances.....	24.56	
Mucilage, starch, and digestible fiber.....	31.97	
Woody fiber.....	11.47	
Ash.....	6.20	
Moisture.....	14.90	} parts in 100.

The proximate substances contained in the seeds may be conveniently divided into four: (1) mucilage, (2) albumen, (3) sugar, (4) fixed oil. Of these only Nos. 1 and 4 will be considered now.

Mucilage.—This is a universal constituent of plants, although found in some under different modifications. According to Thomé, linseed mucilage is formed by the conversion of the epidermal cells into mucilage by the excessive thickening of the cell wall; the innermost layers under the influence of water swell to an extraordinary extent and burst the outer layers, emerging from them as a transparent mucilage. It may, therefore, be considered as a product of the transformation of the cell-wall. It is contained in the testa of the seeds. It may be obtained from them by boiling with water (by which means it will be obtained in thick threads) or by shaking the seeds with acidulated water, filtering, heating to coagulate albumen, concentrating, and precipitating with alcohol. It is less transparent and brittle than ordinary gum, insoluble in cold water or alcohol. In a dry state it contains about 10 per cent. of mineral substances, but if freed from these and dried at 110° C. it yields a formula corresponding to $C_{12}H_{20}O_{10}$ (similar to althæa mucilage). With boiling nitric acid it gives crystals of mucic acid. The mineral constituents contained in it are chiefly phosphates of potassium, magnesium, and calcium. The seeds yield about 15 per cent. of mucilage. It is a most useful material for luting stoppers and other such joints in glass works.

Fixed Oil.—This is obtained from the seeds with or without the aid of heat. Preliminary to pressing, the seeds are crushed to a fine meal. For the finest quality of cold-drawn oil this meal is inclosed in horse hair envelopes, and pressed either by means of wedges, in a screw press, or in a special form of hydraulic press. The cake left may then be submitted to heat and again pressed. Practically, cold drawn oil is seldom prepared, but after the seeds have been ground they are roasted (to destroy mucilage) and the oil expressed. The yield of oil is from 23 to 33 per cent. According to Mr. E. Woolsey, the quantity of oil varies according to the weight, quality, and kind of seed used, and his experiments show that the quantity of oil extracted is from thirteen to twenty gallons per quarter, and that the seed known in commerce as "Best Odessa" yields the most oil. Ladureau states that Russian linseed grown in France becomes valueless after the second generation, and the ash is found to lose more than half its phosphates (*Chem. Soc. Journ.*, 1880). Elaborate descriptions of the machinery employed for extracting the oil may be found in Ure's "Dictionary of Arts."

When expressed without heat, linseed oil presents very little color and no unpleasant taste, but the commercial oils are usually dark yellow, with a peculiar taste and odor. According to Sassure's analyses, it contains:

Carbon.....	75.17	} parts in 100.
Hydrogen.....	10.98	
Oxygen.....	13.85	

corresponding to the formula $C_{18}H_{32}O_2$. Chemically it is a glyceride of linoleic acid. By saponification it yields glycerin and fatty acids, oleic, palmitic (Schuler), myristic, and linoleic. If boiled for some time it loses weight, becomes thick, and dries up readily to a solid transparent varnish, called linoxyn ($C_{18}H_{30}O_2$). Heated to 323° C. it takes fire and leaves tar and charcoal, but if interrupted by closing the vessel, a brown turpentine body will be left, similar to bird-lime. Bromine and chlorine will combine with the oil at a temperature of 50° to 80° C., yielding dark brown liquids, known as brominated and chlorinated linseed oils, and having the formulae represented by $C_{18}H_{30}Br_2O_2$ and $C_{18}H_{30}Cl_2O_2$. With H_2SO_4 (specific gravity 1.478) it is turned green; with strong sulphuric acid it is turned yellow-brown, coagulated, and at last formed into a tough, ropy mass, which, mixed with water or spirit, has been used for precipitating gelatin under the name of "Hatchett's artificial tannin." Exposed to the air it absorbs oxygen and forms a resinous mass called oxylinoleic acid ($C_{18}H_{30}O_3$), and this takes place much more rapidly if the oil be heated. In combining with oxygen it evolves much heat, and has been known to cause

* Recent papers read before the School of Pharmacy Students' Association, London.

* *Journal Royal Agricultural Society*, 2d series, vol. xvi., p. 659.

the inflammation of cotton waste. It is soluble in 5 parts of boiling water, 32 parts of alcohol, and 1-6 parts of ether, and it will dissolve sulphur, selenium, arsenic, and phosphorus. Sulphur dissolved in four times its weight of oil forms a brown viscid mass, known as "fatty balsam of sulphur." A solution (6 in 1) is contained in the non-official formulary of the Dutch Society for the Advancement of Pharmacy (*New Remedies*, 1883). Boiled with dilute nitric acid it becomes thick and hardens in the air to a substance possessing the property of softening in warm water and resembling caoutchouc.

The oil obtained from linseed belongs to that class known as "drying," and these are of sufficient importance to warrant our consideration.

Drying Oils.—This is a division of fixed oils, which, when exposed to air, absorb oxygen and ultimately become converted into a yellowish supple varnish. They contain a glyceride different from non-drying oils, and yield by saponification, linoleic or some similar acid. It is probable that they contain a glyceride of linoleic acid, stearin and palmitin, by the varying proportions of which their differences are determined. They are not solidified by treatment with nitrous acid and mercuric nitrate, and they are distinctly heavier than non-drying oils.

The following is a list of the principal drying oils, together with specific gravities and solidifying points:

Cress seed oil	Lepidum sativum . . .	0.924-15° C.
Deadly nightshade	Atropa Belladonna . .	0.925-27° C.
Gourd seed	Cucurbita Pepo	0.9231-15° C.
Grape seed	Vitis vinifera	0.9202-11° C.
Hemp seed	Cannabis sativa	0.93075-27.5° C.
Linseed	Linum usitatissimum . .	0.935-20° C.
Poppy seed	Papaver somniferum . .	0.927-18° C.
Sunflower seed	Helianthus annuus . . .	0.925-16° C.
Scotch fir	Pinus sylvestris	0.931-30° C.
Tobacco seed	Nictiana tabacum	0.923-15° C.
Walnut seed	Juglans regia	0.928-18° C.

Those in common use are linseed and nut, hemp, and poppy seed oils.

Linoleic Acid.—This acid belongs to the $C_{18}H_{32}O_2$ group. Its formula is $C_{18}H_{32}O_2$ or $C_{18}H_{31}COOH$. It occurs in linseed and poppy seed oils, and probably in all drying oils. It may be prepared from linseed oil by saponifying, purifying the soap by salting out, dissolving in excess of water, and then throwing down by excess of calcium chloride. The precipitate, which is linoleate of calcium, is washed, pressed, and digested in ether, which dissolves it. The ethereal solution is decomposed by hydrochloric acid, linoleic acid being formed, which is soluble in the ether. The ether is then distilled at a low temperature in a stream of hydrogen, leaving impure linoleic acid. It may be purified by dissolving in alcohol, precipitating as a barium salt with ammonium chloride and barium chloride, washing, pressing, and again dissolving in ether. This is then decomposed with hydrochloric acid, the ethereal layer drawn off, redistilled in a current of hydrogen, and finally dried in a vacuum over sulphuric acid.

Mulder estimates it approximately by saponifying, dissolving the mixed fatty acids in alcohol, carefully evaporating, crystallizing out the palmitic and myristic acids, and converting into lead salts. The oleate and linoleate of lead may then be extracted with ether, and the linoleate separated by repeated evaporation in air and resolution in ether (*Amer. Journ. Pharm.*, xl., 249).

Linoleic acid is a yellowish limpid liquid, insoluble in water, soluble in ether and alcohol, having a weak acid reaction. On exposure to air it oxidizes to a thick, viscid mass. Its salts are very easily oxidized. Nitrous acid and mercuric nitrate do not form elaidic acid with it. The formula attributed to it is doubtful. If correct, the acid is isomeric with palmitic and homologous with sorbic ($C_{18}H_{32}O_2$) and stearic ($C_{18}H_{36}O_2$) acids.

Uses of Linseed Oil.—The principal use of the oil is in the preparation of oil paints and varnishes, but it is also used in the preparation of linoleum, oil cloths, printing inks, and gummed silks. For painting and varnishing it is used either as raw or boiled oil. Boiled oil is prepared by boiling the raw oil for two hours, ladling off scum, and then adding a certain proportion of "driers." The substances used for this purpose are kept as trade secrets, but they are generally composed of equal parts of minium and litharge, or a mixture of these with other substances, such as manganese dioxide, lead acetate. Messrs. E. Barruel and Jean recommend that the resinification be effected with manganese borate. After the admixture of "driers" the oil is again boiled for some hours, and after cooling stored in tanks so that the uncombined driers may settle to the bottom. The theory of boiling has been differently explained and is not understood. Liebig suggested that by the process the mucilage and foreign matters were removed; Chevreul, that the chemicals oxidize the oil, and thereby induce a more rapid absorption from the air.

Adulterations of Linseed Oil.—The substances used for this purpose are very numerous. Not alone are the seeds mixed with other kinds before expression, but the oil itself is frequently sophisticated. Nearly all but the very best samples are impure. The principal adulterations are cotton, rape, poppy, and hemp seed oils and resin, mineral and fish oils. These adulterations are very difficult to detect, although the following tests are useful in determining them:

(1) **Density.**—The true oil varies from 0.932 to 0.937; boiled oil from 0.940 to 0.941. Mineral and seed oils are lighter, resin oil is heavier. All the samples of commercial oils that I have tested have been lighter, and have varied from 0.930 to 0.931.

(2) **Solidifying Point** of pure oil is $-27^{\circ}C$, but samples containing other seed oils freeze at a higher temperature.

(3) **Elaiden Test.**—This consists in treating the oils with nitric acid and copper, or nitrous acid and mercuric nitrate. The non-drying oils are converted into a more or less solid mass of "elaiden." By this means almond, olive, rape, and castor seed oils may be detected. I exhibit a number of different "elaidens" obtained from different oils.

(4) **By passing Chlorine into the Oil.**—If fish oils be present, the color will change from brown to black. Fish oils may also be detected by the action of nitric acid. Ten grammes of the oil suspected to contain fish oil may be treated with 3 grammes of nitric acid, stirred, and left to separate. Pure oil becomes green and then a dirty yellow green, whereas a mixed oil becomes dark brown and even black.

(5) **Flashing Point.**—A mixture of hydrocarbons with linseed oil always diminishes the flashing point. The true flashing point of linseed is $283^{\circ}C$, whereas Mason has found that samples of oil mixed with hydrocarbons present a flashing point as low as $128^{\circ}C$.

(6) **Behavior with H_2SO_4 .**—When 50 c. c. are mixed with 10 of strong sulphuric acid, a rise of temperature from 14° to $184^{\circ}C$ takes place, whereas with sunflower, poppy, olive,

and almond, the rise in temperature is between 14° to $90^{\circ}C$. (Dragendoff's "Plant Analysis," translated by Greenish).

The principal adulterations of boiled oil are resin and resin oil. Allen states that the latter may be detected by titrating with alcohol and alkali, and extracting with ether. By evaporating to dryness the resin may be extracted and recognized by taste and smell, and even in favorable circumstances presenting the physical characters of resin.

Adulterations of Linseed Cake.—According to Holderfleiss, Ranuad, and Corenwinder (*Jour. Chem. Soc.*, 1882-83), it is largely adulterated with rape cake, hemp and colza seeds, and other seeds belonging to the Cruciferae. Rape and colza seeds may be detected by Maiboh's test. Boil with potassium hydroxide, filter, and test with lead acetate paper. A black color indicates sulphur present in cruciferous seeds. The presence of these seeds, as stated by Greenish and others, is highly injurious in their use in medicine.

Much of my information has been derived from the works of Allen, Gmelin, Watts, and others, and also from original papers by various authors, most of which have been acknowledged when referred to. I am also indebted to and desire to thank Mr. Dunstan for laboratory assistance, Mr. Earle for samples, and Mr. Walker for practical details.

THE LOSS OF NITER IN THE MANUFACTURE OF SULPHURIC ACID.

The *Journal* of the American Chemical Society quotes from an English source the results of some tests made by Mr. G. Eschellmann, at the Widnes works of Messrs. J. Muspratt & Sons:

The niter used was from 2.75 to 3.24 per cent. of the sulphur. Of the niter used, from 10.7 per cent. to 12.5 per cent. of this was left unabsorbed. The mechanical losses represent 22 per cent., distributed as follows:

	Per cent.
1. At Glover Tower	1
2. Gay-Lussac Tower	19
3. Leakage, etc.	2

As to chemical losses by reduction of nitrogen oxides, calculation showed that an increase of steam by one-third would only raise the temperature of the first chamber by 2.6° degrees. The variation in temperature due to that of the external air amounted to less than 5 degrees in twenty-four hours. The variation due to potting was found to be from 48 to $68^{\circ}C$, showing lowest when the niter pot was nearly exhausted. A fall in temperature indicates less vitriol made. Loss by reduction results from fall of temperature or excess of water. In an experiment where vitriol with four equivalents of water was made instead of three, the loss by reduction amounted to 10.5 per cent. of the niter. Excess of oxygen caused a loss of sulphur, and a fall of temperature in the chambers. With less than 3 per cent. of oxygen, much extra niter is required. To the above table the author adds 31½ per cent. of loss from steam at the inlets, leaving still over 46 per cent. unaccounted for.

CHLOROPHYL PROBABLY A COMPOUND OF IRON WITH ONE OF THE GLUCOSIDES.

By Dr. A. B. GRIFFITHS, F.C.S., Membre de la Société Chimique de Paris, etc.

MANY chemists and other scientific men have been working of late on the constitution of the green coloring matter of plants. The latest researches are those of Dr. Edward Schunck, F.R.S. (*Proceedings of the Royal Society*, vol. xxxvi., p. 183). In these interesting researches he shows that most probably chlorophyll is a glucoside. He makes an extract of leaves in boiling alcohol; the extract is allowed to settle, and then filtered; the deposit on the filter is mixed and shaken up with its own volume of ether and with about two volumes of water. The liquid then divides into two strata—the upper green one (a), which Dr. Schunck says contains all the chlorophyll, and a lower yellow one, which contains tannic acid, a yellow coloring matter, a substance giving a glucose reaction with Fehling's solution (this glucose, I venture to say, is derived from the protoplasm of the plants, for I have found glucoses* in the protoplasm of living and dead cells of *Spirogyra*). Dr. Schunck now separates the two liquids, and the upper one is shaken up with a fresh quantity of water and ether until the lower layer does not give the glucose reaction. The upper liquid leaves on evaporation a green residue. If this residue be dissolved in alcohol and treated with sulphuric acid, and the alcohol evaporated off, then on adding Fehling's solution the glucose reaction is produced; thus proving that green leaves of all plants contain a glucoside, and that this glucoside, says Dr. Schunck, is very likely chlorophyll.

Now, by taking some of Dr. Schunck's green residue from the upper liquid (a), already referred to, dissolved in alcohol, and adding a solution of potassium ferricyanide, a blue color was produced, most probably indicating the presence of iron.

In a previous memoir (*Transactions of the Chemical Society*, 1883, p. 195, and the *Journal of the Royal Microscopical Society*, 1883, p. 536) I have shown the existence of crystals of ferrous sulphate in close proximity to the chlorophyll granules of certain plants. It is most probable that iron enters into the constitution of green chlorophyll; perhaps it is a complex molecule of iron and this glucoside of Schunck. We know that no green colored chlorophyll is produced in plants growing in soils, solutions, or other media deprived of iron. Iron, therefore, plays a most important part in the life of all plants; indirectly it is the means of the process of assimilation taking place, and also the manufacture of starch, sugars, gum, cellulose, etc., in the cells of plants.

From my already published researches† on the value of ferrous sulphate as a manure, I may say that the iron acts most probably as the food for the chlorophyll granules, and the sulphur as the food for the protoplasm of the cells, etc.; for I have grown plants to maturity in a solution containing all the inorganic salts requisite for plant life. But the whole of the sulphur in solution was in the form of sulphate in combination with dyadic iron, and not in combination with calcium or sodium; thus showing that the sulphur of the ferrous sulphate (my new manure) nourishes or acts as a food

* "Notes on Loew and Bokorny's Researches on the Probable Aldehydic Nature of Albumin." *Chemical News*, vol. xviii., p. 179; *Journal of the Royal Microscopical Society*, April, 1884, p. 249; *Journal of the Chemical Society*, 1884 (abstracts), p. 202.

† "Experimental Investigations on the Value of Iron Sulphate as a Manure for Certain Crops," *Transactions of the Chemical Society*, 1884, pp. 71-76; and the *Evening Telegraph* of Philadelphia, U. S. A., March 8, 1884.

for the protoplasm or the albuminous parts of the vegetable organism, for I have found that plants will not grow if entirely deprived of sulphur in some form or other.

From my recent work on this subject it is not improbable that in the chlorophyll cells the molecules of ferrous sulphate which are taken up by the roots are constantly being decomposed, the iron combining with the colorless variety of this glucoside, (i. e., the leucoplastids of the vegetable physiologist), forming the green glucoside (chlorophyll):

and the sulphur going to nourish the protoplasm.

Probably this or similar metamorphoses continue throughout the life of the plant, for, as Liebig says:

"Vitality is the power which each organ possesses of constantly reproducing itself, and for this it requires a supply of substances which contain the constituent elements of its own substance and are capable of undergoing transformation."—*Chem. News*.

ON THE CONSTITUTION OF CHLOROPHYL.*

By EDWARD SCHUNCK, F.R.S.

AN examination of some products derived from chlorophyll, which has occupied me for some time, has led to the question of the true nature and constitution of chlorophyll, a question on which widely different opinions prevail. Without entering into matters which concern the physiologist only, it may be said that to the chemist chlorophyll is simply an organic coloring matter, the substance to which the green color of leaves and other parts of plants is due. Now, coloring matters are of three kinds.

To the first class belong such as occur ready formed and in a free state in vegetable and animal organisms, such as the coloring matters of turmeric and safflower. The second class comprises those that are formed from colorless chromogens by the combined alkalies and oxygen, the coloring matters of logwood and archil being well known examples of this class.

These coloring matters change rapidly when exposed to the further action of oxygen in the presence of alkali, but are quite stable when in contact with acids. The third class consists of glucosides, bodies which do not undergo any considerable change under the influence of alkalies, but are rapidly decomposed when acted on by acids or ferments, yielding, on the one hand, some kind of glucose, and on the other, substances in which the tinctorial properties of the parent substance are much more pronounced.

To this division belong the coloring matters of madder, quercitron, cochineal, etc. Now, chlorophyll in its general properties so much resembles the members of the last class, that one cannot help suspecting that to this class it may belong—that it is, in fact, a glucoside. It shows considerable stability in the presence of alkalies, but acids decompose it rapidly, giving rise to substances which are intensely colored, and show a power of absorbing particular parts of the spectrum much more strongly than chlorophyll itself. Whether, along with the latter bodies, it yields by decomposition with acids some kind of glucose seemed to me a question worthy of attention.

If it was possible to obtain chlorophyll in a state of purity, it would be very easy to settle this question; unfortunately all attempts hitherto made to separate and purify chlorophyll have ended in its decomposition. I consider it as certain that the so-called crystallized chlorophyll which has been described by several authors is in fact a derivative of chlorophyll formed during the process employed for preparing it.

It is, however, very easy to obtain a solution of chlorophyll which shall be quite free from everything soluble in water extracted at the same time from the plant, and therefore free from ready-formed glucose. In order to effect this I proceed as follows: Having extracted leaves of any kind with boiling alcohol, I allow the extract to stand for some time, filter off the deposit which usually forms, and then mix it with its own volume of ether and with about two volumes of water, shaking up well.

The liquid now separates into two layers, an upper green one, containing all the chlorophyll of the extract, and a lower bright yellow one, which contains tannin, a yellow coloring matter, a substance giving the glucose reaction with Fehling's solution, and probably other substances besides. The two liquids are separated in the usual way, and the upper one is shaken up with fresh water, which now usually only shows a trace of color.

This process of washing may be repeated, adding each time a little fresh ether, until the lower layer ceases to give the glucose reaction. The upper liquid leaves on spontaneous evaporation a bright green residue, which, though far from being pure chlorophyll, is free from everything soluble in water, and may therefore be employed to determine whether anything soluble in water, such as glucose, is formed by the action of acids on it. If some of the residue be treated with concentrated sulphuric acid in the cold it dissolves, forming a green solution, which, after standing for some time, gives, on the addition of water, a dark green precipitate.

This precipitate consists essentially of two substances, the phyllocyanin and phylloxanthin of Frémy, which are undoubtedly products derived from chlorophyll, showing the absorption-bands of what is usually called "acid chlorophyll." The liquid filtered from this precipitate, when mixed with copper sulphate and an excess of caustic alkali, becomes blue, and the mixture, on boiling, deposits cuprous oxide.

The experiment may be made in a slightly different manner. The residue left by the green ethereal solution of chlorophyll having been dissolved in alcohol, sulphuric or hydrochloric acid is added to the solution, which is then boiled for some time, evaporated so far as to drive off most of the alcohol, filtered from the products insoluble in water, made alkaline, then mixed with Fehling's solution and boiled, when the usual glucose reaction takes place. In order to make sure that the reaction was not due to ready-

* A paper read before the Royal Society, Dec. 20, 1883.