that Lowitz’s honey sugar is identical with a crystallizable sugar present largely in the juice of the grape. Proust’s investigations extended to other sweet vegetable juices also. All those investigated by him owed their sweetness to one or more of only three species,—(1) cane sugar, (2) grape sugar, (3) (amorphous) fruit sugar. Proust’s results obtain substantially to this day ; a number of new sugars strictly similar to these three have been discovered since, but none are at all widely diffused throughout the organic kingdom.

The quantitative elementary composition of cane sugar was determined early in the 19th century by Gay-Lussac and Thénard, who may be said to have virtually estab­lished our present formula, C12H22O11. Under Fermenta­tion (vol. ix. p. 93) it has been explained how Gay-Lussac (in 1811) came to mis-correct his numbers so as to bring them into accordance with what we now express by C6H12O6 = 1/2C12H24O12. Dumas and Boullay, some years later, found that cane sugar is what Gay-Lussac and Thénard’s analysis makes it out to be, while the “ corrected ” numbers happen to be correct for grape sugar. Dumas and Boullay’s research completed the foundations of our present science of the subject. “ Sugar ” is now a collect­ive term for two chemical genera named *saccharoses* (all C12H22O11) and *glucoses* (all C6H12O6). All sugars are colourless non-volatile solids, soluble in water and also (though less largely) in aqueous alcohol; from either solvent they can in general be obtained in the form of crystals. The aqueous solution exhibits a sweet taste, which, however, is only very feebly developed in certain species.

All sugars and their solutions have the power of turning the plane of polarization of light. In a given solution of a given kind of sugar the angle α through which the plane is turned is governed by the equation α=±[α]*lp*, where *l* stands for the length of solu­tion traversed (the customary unit of length being the centimetre) and *p* for the number of grams of dry sugar present in a volume of solution equal to that of (say) 100 grams (3·52 oz.) of water, where, however, “gram” must be taken as merely a convenient word for “unit of weight” ; ±[α], *i.e.* the special value of α for *l*=l and *p=l,* is called the specific rotatory power of the sugar operated upon. The sign ± indicates that the plane of polarization is turned either to the right or to the left according to the nature of the species. For a given species and a given temperature [α] has a constant value. Supposing its value to have been determined by standard experiments and *l* to be known (or to be kept constant throughout and taken as unit of length), the determination of α for a given solution suffices for the calculation of *p.* This method is largely used industrially for the assaying of cane sugar.

Sugars, though neutral to litmus and inert towards such substances as carbonates on the one hand and aqueous acids *(qua* acids) on the other, combine with strong bases, such as caustic potash, baryta, and lime, into *saccharates,* and, when brought into contact with the strongest nitric acid (or a mixture of the same with oil of vitriol) or (at the proper temperature) with acetic anhydride, unite with these into nitrates and acetates respectively, with elimination of water. These nitrates, &c., are related to the respective sugar exactly as (to take an analogous case) nitrate of methyl, CH3(NO3), is to methyl-alcohol, CH3(OH) ; only in the case of a sugar a plural of NO3's is capable of entering into every one molecule and turning out so many HO’s ; hence sugars are said to be *polyvalent alcohols.* Of the several points of difference between saccharoses and glucoses the most important is that, while the latter remain unchanged when boiled with highly dilute sulphuric or hydrochloric (or certain other kinds of) acid, the former take up water and every molecule breaks up into two molecules of glucose, which in general are of different kinds. Cane sugar, for instance, yields *dextrose* and *lævu­lose* (so called from the direction in which they turn the plane of polarized light), thus—

C12H22O11 + H2O = C6H12O6 + C6H1206

Cane sugar turns the plane of polarized light to the right; the mixed glucose produced is lævo-rotatory ; hence the process is spoken of technically as involving the *inversion* of cane sugar, and the mixed product is called *invert sugar.* The term “ inversion, ” however, has come somehow to be used for all decompositions which fall under the above equation ; occasionally it is used even in a wider sense, to include any decomposition of a carbo-hydrate *(e.g.,*

starch) into two less complex carbo-hydrates.

All sugars are liable to fermentative changes ; a special character of the three principal vegetable sugars is that, when brought into contact as solutions with yeast (living cells of saccharomyces), under suitable conditions, they suffer vinous fermentation, *i.e.*, break up substantially into carbonic acid and alcohol. Dextrose and lævulose break up directly,—C6H12O6 = 2C2H6O + 2CO2. Cane sugar first, under the influence of a soluble ferment in the yeast, gets inverted, and the invert sugar then ferments, the dex­trose disappearing at a greater rate than the lævulose.

It is remarkable that no sugar has ever been produced artificially even in the sense of being built up from other native organic substances of less chemical complexity. It is easy to produce dextrose from starch, or lævulose from inulin, or both from cane sugar, by inversion ; but none of these processes is reversible by known methods. Yet the problem of producing cane sugar artificially may in a sense be said to have found a virtual solution at the hands of a German-American chemist, Fahlberg.@@1 Fahlberg, by subjecting toluene, C6H5CH3 (one of the components of coal-tar naphtha), to a series of operations has produced

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from it a body, C6H4CONH, which he called *saccharine,*

because he found it to be about 230 times as sweet as cane sugar. This saccharine is a white crystallized solid, only slightly soluble in cold water, but sufficiently so to admit of its incorporation with jellies, puddings, bever­ages, &c. A mixture of one part of it with 1000 parts of ordinary grape sugar (as produced industrially from starch) is as sweet as the best cane sugar. The substance, though an antiseptic, is said to be perfectly innocuous.

*Glucoses.*

Of these a pretty large number are now known, but only lævu­lose and dextrose need be noticed here. Both are largely present in all kinds of sweet fruit juices and in honey. In most of these materials they are accompanied by a small proportion of cane sugar, which forcibly suggests that the glucose in fruit juices is really inverted cane sugar. But, in opposition to this surmise, the proportion of cane sugar in oranges increases during the process of ripening, and the sourest of all fruits—the lemon—contains four parts of cane for every ten of invert sugar ; besides, the juices of grapes and sweet cherries contain no cane sugar whatever. Accord­ing to Stammer, the young leaves of the sugar cane contain abun­dance of invert sugar, which gradually disappears and gives way to cane sugar as the leaves develop and ultimately dry up. In the living body of man dextrose is constantly being produced from the glycogen of the liver, to be taken up by the blood and oxi­dized into carbonic acid and water. In certain diseases, however (see Nutrition, vol. xvii. p. 681), the sugar survives and passes into the urine ; as much as one pound avoirdupois may be dis­charged by a diabetic patient in twenty-four hours. A numerous class of vegetable substances, known as *glucosides,* contain glucose of some kind in the sense that, when decomposed by boiling dilute sulphuric acid or by the action of certain ferments, they split up into glucose and some product;—not a sugar—which is characteristic of the respective species. For examples, see Fer­mentation, vol. ix. p. 96.

*Dextrose* is being produced industrially from starch by inversion (see below), and sold as grape sugar. Such grape sugar, however, is very impure. For the preparation of pure dextrose rich diabetic urine, honey, and cane sugar are convenient materials. The method recommended by Soxhlet is to dissolve 160 grams (5·64 oz.) of powdered cane sugar in a mixture of 500 c. c. of alcohol of 85 per cent. by weight and 20 c.c. of fuming hydrochloric acid at 45° C. and to allow the solution to stand. After about a week dextrose begins to crystallize out, and, if the mixture is being frequently agitated, the deposit of crystals increases gradually. A small crop of crystals thus obtained suffices for inducing crystallization in a large supply of fresh liquor. Dextrose crystallizes from its highly concentrated aqueous solution—somewhat tardily—in minute soft crystals, united into warts or cauliflower-like masses, which contain 1H2O of crystal water beside C6H12O6. The crystals lose their water at 100° C. From absolute alcohol it crystallizes as C6H12O6. It dissolves in 1·2 parts of cold and far less of boiling water. 100 parts of alcohol of 0·837 specific gravity dissolve 1·94 parts at 17·5 C. and 21·7 parts on boiling. In a given volume of aqueous solu-

@@@1 See *Amer. Chem. Jour.,* i. p. 170, ii. p. 181, and i. p. 425 ; short notices in *Jour. Soc. Chem. Ind.,* iv. p. 608, and February 1886.