METHODIUS, the apostle of the Slavs, was a native of Thessalonica, and was born about the year 825. His nationality is unknown, but most probably he was a Græcized Slav; the family of which he was a member appears to have been one of considerable social distinction, and he himself had already attained high official rank in the government of Macedonia before he determined to abandon his secular career and embrace the monastic life. His younger brother Constantine (better known as Cyril, the name he adopted at Rome shortly before his death) had also distinguished himself as a secular "philosopher" in Constantinople before he withdrew to the cloister and to solitude. Constantine about 860 had been sent by the emperor Michael III. to the Khazars, in response to their request for a Christian teacher, but had not remained long among them; after his return to within the limits of the empire, his brother and he laboured for the instruction of the Slavonic or Slavonicized population, especially by means of translations of the Scripture lessons and the liturgical books used in Christian worship. About the year 863, at the invitation of Rastislav, king of "Great Moravia," who desired the Christianization of his subjects, but at the same time that they should be independent of the Germans, the two brothers went to his capital (its site is unknown), and, besides establishing a seminary for the education of priests, successfully occupied themselves in preaching in the vernacular and in diffusing their religious literature. After four years they seem to have received and accepted an invitation to Rome from Pope Nicholas I., who had just been engaged in his still extant correspondence with the newly converted Bulgarian king; his death occurred before their arrival, but they were kindly received by his successor Hadrian II. Constantine died in Rome, but Methodius, after satisfying the pope of his orthodoxy and obedience, went back to his labours in "Moravia" as archbishop of Pannonia. His province appears to have been, roughly speaking, co-extensive with the basins of the Ráab, Drave, and Save, and thus to have included parts of what had previously belonged to the provinces of Salzburg and Passau. In 871 complaints on this account were made at Rome, nominally on behalf of the archbishop of Salzburg, but really in the interests of the German king and his Germanizing ally Swatopluk, Rastislav's successor; they were not, however, immediately successful. In 879, however, Methodius was again summoned to Rome by Pope John VIII., after having declined to give up the practice of celebrating mass in the Slavonic tongue; but, owing to the peculiar delicacy of the relations of Rome with Constantinople, and with the young church of Bulgaria, the pope, contrary to all expectation, ultimately decided in favour of a Slavonic liturgy, and sent Methodius (880) back to his diocese with a suffragan bishop, and with a letter of recommendation to Swatopluk. This suffragan, a German named Wiching, unfortunately proved quite the reverse of helpful to his metropolitan, and through his agency, especially after the death of John VIII. in 882, the closing years of the life of Methodius were embittered by continual ecclesiastical disputes, in the course of which he is said to have laid Swatopluk and his supporters under the ban, and the realm under interdict. The date of the death of Methodius is variously given; the most trustworthy tradition says that it took place on April 6, 885. He was buried at Welehrad (probably Stuhlweissenberg). The Greek Church commemorates St Cyril on February 14 and St Methodius on May 11; in the Roman Church both are commemorated on March 9.

See Schafarik's *Slawische Alterthümer*, where the original authorities are fully referred to. The subject of the present notice is most probably not to be identified with the Methodius, a painter and monk, who, according to a well-known legend, converted Boris of Bulgaria by means of a picture of Christ's second coming.

METHYL, a chemical term which until lately was used in two radically different senses, namely, as designating either the atom-group CH_3, which in numberless chemical formulæ figures as a "radical" (compare CHEMISTRY, vol. v. p. 552), or a gaseous substance of the same composition, which, however, nowadays is generally called "dimethyl," to distinguish it from the radical. A gas of the composition and the specific gravity ($C_2H_6 \div H_2 = 15$) corresponding to C_2H_6 can be produced in two principal ways,—first, by the decomposition of zinc-ethyl by water (Frankland)—

$$Zn(C_2H_5)_2 + 2OH\,.\,H = Zn(OH)_2 + C_2H_5H\,;$$

and, secondly, by the electrolysis of acetate of potash solution (Kolbe), we have virtually

$$2CH_3\,.\,COOH = \underset{+\text{pole.}}{(CH_3)_2 + 2CO_2}\ \Big|\ \underset{-\text{pole.}}{+H_2}.$$

These two gases used to be distinguished as two different substances,—Frankland's being looked upon as hydride of ethyl, $C_2H_5\,.\,H$, Kolbe's as "real methyl" $(CH_3)(CH_3)$, until Schorlemmer proved their identity by showing that both, when treated with chlorine, yield the same identical chloride of ethyl, $C_2H_5\,.\,Cl$. This confirmed the now generally adopted notion that the radical ethyl itself is nothing but methylo-methyl, $H_3C—CH_2*$, so that the filling up of the gap* by an H must necessarily produce "hydride of ethyl" and "dimethyl" in one. The "true methyl" which chemists used to dream of, and which, when treated with chlorine, would yield two CH_3Cl's analogous to $HH + ClCl = HCl + HCl$, does not, and according to our present knowledge cannot, exist. A quasi apology for it is "marsh gas," CH_4, the principal component of the gas mixture which bubbles up from any marshy pond when its mud is stirred up with a stick. It is always produced when vegetable matter decays in the presence of water, and in the relative or absolute absence of air. What everybody knows as "fire-damp" is nothing but a (necessarily explosive) mixture of air with impure marsh gas, produced in the constantly progressing metamorphosis of the coal deposits; in certain districts streams of marsh gas are issuing forth from cracks in the earth; the "holy fire" of Baku is such a marsh-gas spring, which, having once caught fire by accident, continues burning to this day. Perfectly pure marsh gas can only be obtained from zinc-methyl, $Zn(CH_3)_2$, by its decomposition with water (*vide supra*); a nearly pure preparation is procurable by heating a mixture of acetate of potash or soda and caustic alkali to dull redness:—

$$\underset{\text{Acetate.}}{CH_3\,.\,COONa} + NaOH = \underset{\text{Carbonate.}}{Na_2CO_3} + CH_3H.$$

Marsh gas can be prepared synthetically by the action of bisulphide of carbon vapour and sulphuretted hydrogen (both producible from their elements) on red-hot copper, $CS_2 + 2H_2S + 8Cu = 4Cu_2S + CH_4$ (Berthelot). A mixture of marsh gas and chlorine, when exposed to direct sunlight, explodes with formation of hydrochloric acid and charcoal. In diffuse daylight only part of the hydrogen is eliminated and "replaced" by its equivalent in chlorine, which in general leads to the formation of four bodies: $CH_3Cl = CH_4 + Cl_2 - HCl$, chloride of methyl; CH_2Cl_2, chloride of methylene; $CHCl_3$, chloroform; CCl_4, tetrachloride of carbon. Of these several chloromethanes, as they are called, the first here interests us more than any of the rest, because from it any other methyl compound can be produced by the substitution of the proper kind of radical for the Cl of the CH_3Cl. Thus, for instance, we can convert it into methyl-alcohol by treating the chloride with aqueous caustic potash at 100° C. (Berthelot). This is a most important synthesis, because it is this methyl-alcohol that, in practice, always serves as the starting point in the preparation of other methyl compounds.

Methyl-Alcohol.—This substance, in ordinary practice, is never made synthetically, but simply extracted from wood-spirit, a commercial substance which is produced industrially in the dry distillation of wood. The wood-spirit is contained in the aqueous portion of the tar produced in this operation, along with acetic acid. To recover both, the tar-water is neutralized with lime and distilled, when the acetate remains, while the spirit distils over, along with a deal of water, which, however, is easily removed, as far as necessary, by redistillation and rejection of the less volatile parts. The "crude" wood-spirit, as thus obtained, is not unlike in its general properties to ordinary spirit of wine, from which, however, it is easily distinguished by its abominable smell. The ordinary commercial article, besides a variable percentage of water, contains from 35 to 80 per cent. of methyl-alcohol; the rest consists chiefly of acetone, but besides includes dimethyl-acetal, $C_2H_4(OCH_3)_2$, acetate of methyl, and numerous other minor components. In Great Britain large quantities of wood-spirit are used for the making of methylated spirit, a mixture of ordinary spirit of wine with one-ninth of its volume of wood-spirit, which is allowed to be sold duty free for the preparation of varnishes, and for other industrial purposes. In former times, here as elsewhere, wood-spirit itself used to be employed as a cheap substitute for spiritus vini; but this is no longer so, since the aniline-colour industry has created a large demand for pure methyl-alcohol. Hence in some Continental works the wood-spirit, instead of being sent out as such, is being worked up for its components, by the following sequence of operations:—(1) dehydration by lime; (2) heating, under an inverted condenser, with caustic soda, to convert the acetate into hydrate of methyl; (3) destruction of the bad smells by mild oxidation; (4) distillation in a kind of Coffey's still, whereby it is split up into approximately pure alcohol, acetone, and "tails."

The new industry led to the invention of the following technical methods for the determination, in a given spirit, of the percentages of real methyl-alcohol and of acetone.

The alcohol is determined by saturating 5 c.c. of the spirit with hydriodic acid (volatilization of alcohol and iodide of methyl being avoided by means of a cold-water bath and an inverted condenser), and the product poured into water. Iodide of methyl separates out as a heavy oil, which is measured as it is. According to direct trials 5 c.c. of pure methyl-alcohol yields 7·45 c.c. of crude iodide (Krell, Krämer and Grodzky).

For the determination of the acetone the following reagents are required (Krämer):—(1) a solution of iodine, prepared by dissolving $I_2 = 254$ grammes of iodine, by means of (say) 500 grammes of iodide of potassium, in water, and diluting to 1 litre; (2) a solution of caustic soda containing twice (NaOH) grammes per litre; (3) alcohol-free ether. Ten c.c. of the soda are placed in a graduated cylinder and mixed intimately, first with 1 c.c. of the spirit, then with 5 c.c. of the iodine solution. Iodoform separates out (if acetone is present) in minute yellow crystal plates; this product is "shaken out" by means of 10 c.c. of ether, and determined by evaporating an aliquot part of the ethereal layer in a tared watch-glass to dryness and weighing the residue. C_3H_6O yields CHI_3; hence 1 part of iodoform indicates 0·28 parts of acetone.

The formula of methyl-alcohol and its true chemical character were correctly ascertained by Dumas and Péligot as early as 1834; yet pure methyl-alcohol may be said to have been an unknown substance until 1852, when Wöhler taught us to prepare it, by first extracting the CH_3 of the CH_3OH in the wood-spirit as oxalate of methyl, and then decomposing the (purified) oxalate with water.

The most convenient raw material to use nowadays is the commercial "pure" alcohol; if wood-spirit is employed it had better first be purified by distillation over caustic soda (*vide supra*). The formation of the oxalate then is best effected (according to Alexander Watt) as follows:—500 grammes of oxalic acid crystals are mixed with 200 c.c. of oil of vitriol; then 500 c.c. of the spirit are added, the whole kept for a time at 80° C., and then allowed to stand cold for twenty-four hours.

The large crop of oxalate crystals—partly $(CH_3)_2C_2O_4$, partly $CH_3\,.\,H\,.\,C_2O_4$—is separated from the liquor by pressure and subsequent drying over vitriol, and then decomposed by distillation with water.

The aqueous alcohol thus obtained is dehydrated by the well-known methods used in the preparation of ordinary absolute alcohol.

According to Krämer, a purer preparation than Wöhler's is obtained by extracting the methyl as formiate instead of as oxalate, which is easily effected by digesting the wood-spirit with a formic acid of 1·22 specific gravity, and purifying the formic ether by fractional distillation. This ether boils at 32°, the oxalate at 161° C., hence a proper combination of the two methods should be infinitely superior to either. What now follows must, in general, be understood to refer to Wöhler's preparation.

Pure methyl-alcohol is a colourless liquid similar in its general properties, in its behaviour to other chemically inert liquids, and in its action as a solvent to ordinary absolute alcohol, from which, however, it differs by the entire absence from it of all spirituous odour. A preparation which smells of wood-spirit may be condemned at once as impure. According to H. Kopp, its specific gravity is 0·8142 at 0° C. and 0·7997 at 16°·4. If the volume at $t°$ be V, then (from 0° to 61°)

$$V = 1 + \cdot0001134t + 1\cdot364 \times 10^{-6}t^2 + 8\cdot741 \times 10^{-9}t^3.$$

The boiling point is 64°·6 to 65°·2. The tension-curve was determined by Regnault and by Landolt; but the results of the two observers do not agree except (approximately) at P = 760 mm. Methyl-alcohol has quite a characteristic tendency to "bump" badly on distillation, which, however, can be prevented by addition of a small fragment of tin-sodium, which produces a feeble but sufficient current of hydrogen. Its specific heat is ·6713; latent heat of vapour, 26·4; combustion heat, 5307 per unit weight (Favre and Silbermann). The refractive index for the D (sodium) ray is 1·3379 ± ·0013 for 10° ∓ 5° C. (Dale and Gladstone).

Methyl-alcohol mixes with water in all proportions with contraction.

Since Wöhler's discovery a table for the specific gravities of aqueous methyl-alcohols has been constructed experimentally by A. Dupré; but unfortunately his alcohol boiled at 58°·7, and consequently must have been something different from what generally goes by this name.

In its chemical reactions methyl-alcohol, $CH_3\,.\,OH$, is very similar to ordinary (ethyl) alcohol, $C_2H_5\,.\,OH$, and consequently, in the same sense as the latter, analogous to water, $H\,.\,OH$. Thus, for instance, metallic sodium and potassium dissolve in either alcohol with evolution of hydrogen and formation of ethylates or methylates of the alkali metals. Example—

$$CH_3OH + Na = CH_3\,.\,ONa + \tfrac{1}{2}H_2.$$

The two methylates crystallize from the solution with crystal-alcohol, which can be driven off in an atmosphere of hydrogen by heat, without decomposition of the salts themselves. Water at once decomposes them into caustic alkali and alcohol, $CH_3\,.\,ONa + H\,.\,OH = NaOH + CH_3OH$. Yet the reverse reaction takes place when the alcohol is treated with a large excess of caustic soda.

The action of acids on methyl-alcohol is in general quite analogous to that on, for instance, caustic soda, with this important difference, however, that what in the case of NaHO goes on so readily in aqueous solutions with $CH_3\,.\,OH$ succeeds only under circumstances precluding the accumulation of water. In these circumstances we have, for instance,

$$(1)\ Cl\overline{H + OH}\,.\,CH_3 = H_2O + Cl\,.\,CH_3\,;$$

$$(2)\ \underset{\text{Acetic acid.}}{(C_2H_3O_2)}\overline{H + OH}\,.\,CH_3 = H_2O + \underset{\text{Acetic ether}}{C_2H_3O_2\,.\,CH_3}\,;$$

and so on with all monobasic acids. A dibasic acid XHH may act as $(X)H_2$ or as $(XH)\,.\,H$; thus, for instance,

$$(3)\ \underset{\text{Oxalic acid.}}{(C_2O_4H)}\overline{H + OH}\,.\,CH_3 = H_2O + \underset{\text{Methyl oxalic acid.}}{C_2O_4\,.\,HCH_3}\,;$$

$$(4)\ (C_2O_4)H_2 + 2OH\,.\,CH_3 = 2H_2O + \underset{\text{Methyl oxalate.}}{C_2O_4\,.\,(CH_3)_2}\,;$$

A tribasic acid forms two methyl acids and one neutral ether; we have, for instance,

(5) (From PO_4H_3); $PO_4(CH_3)H_2$; $PO_4(CH_3)_2H$; $PO_4(CH_3)_3$.

It would, however, be a great mistake to suppose that whether, for instance (Ex. 3 and 4), the monomethyl or the dimethyl compound is formed depends on the quantity of methyl-alcohol employed per unit of acid. This depends far more largely on other conditions, as will be illustrated in next paragraph. The methyl-salts of oxygen acids are called esters, in opposition to the chloride, bromide, iodide, sulphide, and oxide, which are set apart as ethers. Broadly speaking, ethers are not, while esters are, readily decomposed by water into their cogeners; but the nitrate $CH_3 . NO_3$ behaves in this respect like an ether.

Action with Sulphuric Acid.—Methyl-alcohol mixes with oil of vitriol with considerable evolution of heat and (always only partial) conversion of the two ingredients into methyl-sulphuric acid. Equal volumes of acid and alcohol give a good yield. To prepare pure methyl sulphates, dilute the mixture largely with water, avoiding elevation of temperature (which would regenerate the ingredients), and saturate with carbonate of baryta. Filter off the sulphate of baryta to obtain a solution of the pure methyl sulphate $SO_4 . CH_3 . ba$ (where $ba = \frac{1}{2}Ba = 1$ *eq.*), from which this salt is easily obtained in crystals. From the baryta salt any other methyl sulphate is readily obtained by double decomposition with a solution of the respective sulphate; the acid itself, for instance, by means of sulphuric acid. At higher temperatures the reaction between vitriol and methyl-alcohol results in the formation of methyl-ether, $(CH_3)_2O$, or of normal sulphate of methyl, $(CH_3)_2SO_4$. The ether is a gas condensable into a liquid which, under pressure of one atmosphere, boils at − 21° C.

The gas dissolves in about one thirty-seventh of its volume of water; far more largely in alcohol and in ether; most abundantly in oil of vitriol, which dissolves about six hundred times its volume of methyl-ether gas, thus affording a very handy means for storing up the gas for use. The solution needs only be diluted with its own volume of water to be broken up into its components (Erlenmeyer).

Liquefied oxide of methyl is now being produced on the manufacturing scale, and sold as a powerful refrigerating agent. One part of sulphuric acid is mixed with a little over one part of dehydrated wood-spirit, and the mixture heated to 125° to 128° C. (130° being carefully avoided), when methyl-ether goes off. When the mixture is exhausted, more wood-spirit is added to the residue so as to re-establish the original specific gravity (of 1·29), and the heating resumed, which again furnishes a supply of the gas, and so on. This proves that the process is not, as used to be supposed, one of mere dehydration, but a cycle of reactions analogous to those in the ordinary process of etherification, as shown by the equations:—

(1) $SO_4H_2 + CH_3OH = SO_4 . HCH_3 + H_2O$

(2) $SO_4 . H . CH_3 + H . O . CH_3 = SO_4HH + CH_3 . O . CH_3$

The ester, $SO_4(CH_3)_2$, though obtainable by distillation of the alcohol with 10 parts of vitriol, is more conveniently prepared from pure methyl-sulphuric acid by distillation in vacuum at 130°–140° C; thus:—$2SO_4CH_3\ H = SO_4H_2 + SO_4(CH_3)_2$. It is a colourless liquid, smelling like peppermint, specific gravity 1·327 at 18°; it boils at 187° to 188° C.

Chloride of methyl, CH_3Cl, readily produced by the action of hydrochloric acid gas and hot methyl-alcohol (preferably in the presence of chloride of zinc as an auxiliary dehydrator), is a gas which, under ordinary pressure, condenses into a liquid at − 23° C. The gas, at ordinary temperatures (though very readily soluble in alcohol), is only sparingly absorbed by water, which, however, at 6° unites with it into a solid hydrate. Condensed methyl chloride has become an article of commerce, being largely produced from trimethylamine (*vide infra*) and used as a powerful frigorific agent, as well as for the extraction of perfumes from flowers. Regarding nitrite of methyl, $NO—O—CH_3$, its interesting isomeride nitromethane, $O_2N—CH_3$, and nitrate of methyl, NO_3CH_3, we must refer to the handbooks of organic chemistry.

Iodide of methyl, CH_3, is obtained by distilling methyl-alcohol with hydriodic acid, which latter is best produced off-hand by addition to the alcohol of iodine and amorphous phosphorus. It is a colourless liquid of 2·269 specific gravity, boiling at 42°·5 C., insoluble in water.

Organic Methyl-Esters.—The more volatile ones are in general easily obtained by distillation of the respective acid with methyl-alcohol, or with methyl-alcohol and oil of vitriol (virtually $SO_4 . H . CH_3$); the less volatile ones more conveniently by passing hydrochloric acid gas into a methyl-alcoholic solution of the acid. We have no space for the individual substances; but the salicylate $C_7H_5O_3 . CH_3$ may just be named as being the principal component of the essential oil of *Gaultheria procumbens* (wintergreen oil).

Methylamines.—The general result of the action of ammonia on an ester is the formation of alcohol and acid amide. Example—

$$\underset{\text{Acetate of methyl.}}{(C_2H_3O)—\overline{O—CH_3}} + HNH_2 = CH_3 . OH + \underset{\text{Acetamide.}}{C_2H_3O . NH_2}$$

With iodide of methyl this reaction is an obvious impossibility; what really takes place (as A. W. Hofmann has shown for this and all analogous cases) is that the iodide unites with the ammonia into the HI compound $HI . NH_2CH_3$ of a base NH_2CH_3, which can be separated from the acid by distillation with caustic potash, and when thus liberated presents itself as a gas surprisingly similar (almost to identity) to ammonia. The analogy extends to the action on iodide of methyl, which, in the case of methylamine, NH_2CH_3, leads to the formation of dimethylamine, $NH . (CH_3)_2$; and from the latter again trimethylamine, $N(CH_3)_3$, can be prepared by a simple repetition of the operation. These three amines are closely analogous in their chemical character to ammonia, the points of difference becoming the more marked the greater the number of (CH_3)'s in the molecule. Trimethylamine, having lost all its ammonia-hydrogen, cannot possibly act upon iodide of methyl like its analogues. What it really does is to unite with the iodide into "iodide of tetramethyl-ammonium," $I . N(CH_3)_4$, analogous to iodide of ammonium, INH_4, we should say, if it were not the reverse, because the organic iodide (unlike its prototype, which is an ammonium compound only in theory), when treated with moist oxide of silver (virtually with AgOH), really does yield a solution of a true analogue of caustic potash in the shape of hydroxide of tetramethyl-ammonium, $N(CH_3)_4 . OH$.

In regard to the actual preparation of these several bodies, which is not so simple as might appear from our exposition of their mutual relations, we must refer to the handbooks of organic chemistry. But we must not omit to state that trimethylamine, which only the other day was never seen outside a chemical museum, is now being manufactured on a large scale, and promises to play an important part in industrial chemistry. The waste liquors obtained in the distillation of alcohol from fermented beet-root molasses serve as a raw material for its preparation. These liquors, when evaporated to dryness and subjected to dry distillation, yield, besides tar and gases, an aqueous liquid containing large quantities of ammonia, acetonitrile, methyl-alcohol, and trimethylamine. This liquor is neutralized with sulphuric acid, and distilled, when the nitrile and the methyl-alcohol distil over, to be recovered by proper methods. From the mixed solution of the sulphates of ammonia and trimethylamine the former is separated out as far as possible by crystallization; the mother-liquor

is distilled with lime, the volatile bases are absorbed in hydrochloric acid; the hydrochloric solution is evaporated; and the sal-ammoniac which comes out at first is, as far as possible, fished out. The last mother-liquor is evaporated to dryness, and in this form represents commercial trimethylamine hydrochlorate. It is this product which serves for the preparation of methyl chloride (*vide supra*), the process being founded upon the fact that a concentrated solution of the salt, when heated, breaks up $3HCl . N(CH_3)_3$ into $2N(CH_3)_3$ of free trimethylamine + $NH_2 . CH_3HCl$ of hydrochlorate of monomethylamine and $2CH_3Cl$ of methyl chloride.

These processes are being carried out industrially by Vincent in France. But this base trimethylamine seems destined to do more than provide us with a new refrigerating agent. The attempt has been made—it would appear, with success—to utilize it for the preparation of pure carbonate of potash from native chloride of potassium, just as ordinary ammonia, in the famous ammonia-soda process, serves for the conversion of common salt into soda-ash.

Methyl Cyanides.—There are two distinct bodies which, by composition and by synthesis, are both $CH_3 + NC$; they are named "acetonitrile" (formerly called simply cyanide of methyl) and isocyanide of methyl or methylcarbamine respectively.

Acetonitrile was discovered by Dumas in 1847. It may be prepared by the distillation of a mixture of methylsulphate and of cyanide of potassium; but is obtained more easily and in a purer state by distilling acetamide with phosphoric anhydride. Acetate of ammonia may be used instead of the amide, but it does not work so well.

$CH_3 . CO . O(NH_4)$	$CH_3 . CO . (NH_2)$	$CH_3 . CN$
Acetate of NH_3	Acetamide	Nitrile
= A (say).	= A − H_2O	= A − $2H_2O$.

It is a colourless liquid of a pungent aromatic odour, with specific gravity ·805 at 0°, and boils at 82° C. When heated with aqueous potash (at the wrong end of a condenser) it breaks up with formation of ammonia and acetate of potash. Whence we conclude that the methyl is combined more directly with the carbon of the cyanogen, thus:

$$N\{\overline{C—CH_3}\} + 2H_2O = NH_3 + \underset{\text{Acetic acid.}}{CH_3 . COOH}$$

This conclusion is supported by the action on the nitrile of nascent hydrogen, which leads to the formation of ethylamine, thus (Mendius):—

$$NC—CH_3 + 4H = \underset{\text{Ethylamine.}}{H_2N—CH_2CH_3}.$$

In either case we pass from a monocarbon to a dicarbon body, virtually from methyl to ethyl alcohol.

The isocyanide is prepared by heating iodide of methyl with cyanide of silver (CH_3I; 2NCAg) and ether in a sealed-up tube to 130° to 140°, to produce the crystalline body $AgNC + NCCH_3$ (and AgI). The double cyanide, when distilled with some water and cyanide of potassium, breaks up into its components,—the NCAg forming $(NC)_2AgK$; and the cyanide of methyl distils over. It is a colourless liquid, characterized by quite an unbearably irritating and sickening smell. The specific gravity is ·756 at 14°, the boiling point 59° C. It combines with hydrochloric acid into a crystalline salt which is readily decomposed by water into methylamine and formic acid. Whence we conclude that in this case the cyanogen is tied to the methyl by its nitrogen; thus:—

$$C\{N—CH_3\} + 2H_2O = \underset{\text{Formic acid.}}{H . COOH} + \underset{\text{Methylamine.}}{NH_2 . CH_3}.$$

The methyl here remains methyl, being separated by an N from the cyanogen-carbon, which latter passes into formic acid.

We must not close this section without at least referring to the *methylphosphines*, as being a set of bodies related to PH_3 (phosphine) as the methylamines are to NH_3 (ammonia), and similar to these in their chemical character, in so far as they are bases. The points of difference between the two series are of pretty much the same sense as those between the two prototypes. Thus, for instance, while trimethylamine $N(CH_3)_3$ is a strong base, but inert to oxygen gas, trimethylphosphine is a relatively feeble base, but in contact with air greedily absorbs oxygen with formation of an oxide $P(CH_3)_3O$, the like of which in the nitrogen series has no existence.

Sulphur Compounds of Methyl.—Substances analogous to methyl-alcohol and methyl-ether respectively can be obtained by the distillation of methyl sulphate of potassium with strong solutions of the potassium sulphides KHS and K_2S respectively. The body $CH_3 . SH$ is known as methyl-mercaptane, the other $(CH_3)_2S$ as sulphide of methyl. Both are very volatile stinking liquids. Sulphide of methyl claims a special interest as being the starting point for the preparation of an important class of bodies called trymethyl sulphine compounds. The sulphide $(CH_3)_2S$ readily unites with the iodide CH_3I into crystals of iodide of trimethyl sulphine, $(CH_3)_3S . I$, a substance which is closely analogous in its chemical character to the iodide of tetramethyl-ammonium. Moist oxide of silver, for instance, converts it into a strongly basic hydrate, $S(CH_3)_3 . OH$, which in its avidity for acids almost beats its analogon in the nitrogen family. An investigation of its salts was published by Crum Brown and Blaikie.

Methyl Arsenides.—Arseniferous bases constituted like mono- or di-methylamine (bodies such as AsH_2CH_3, analogous to $NH_2 . CH_3$) do not seem to exist. What we do know of are—(1) a trimethylarsine and the iodide and the hydroxide of tetramethylarsonium,—$As(CH_3)_3$, $As(CH_3)_4I$, and $As(CH_3)_4OH$,—bodies discovered by Cahours and Riche; (2) a whole series of monomethylic bodies, $As(CH_3)X_2$ (where X = Cl, Br, or X_2 = O,S), discovered by Baeyer in 1857; (3) the kakodyle compounds, a series of bodies, $As(CH_3)_2 . X$ or $As(CH_3)_2 . X_3$, which were discovered and investigated by R. Bunsen in 1842. This great investigation marks an epoch in the history of organic chemistry, and our article would not be complete without at least a short summary of its results. Bunsen started in his investigation with a liquid which had been obtained by Cadet as early as 1760, by the dry distillation of equal parts of white arsenic and anhydrous acetate of potash, and which nobody cared to investigate because it emits fumes which have an indescribably sickening smell and an intensity of poisonous action, compared with which that of white arsenic itself appears insignificant. It was reserved for Bunsen to attack this awful substance and force it to give an account of itself. According to Bunsen, Cadet's liquid is substantially an oxide, $(AsC_2H_6)_2O$, which has strongly basic properties, readily exchanging its O for Cl_2, &c. To obtain the pure substance, the liquor is distilled with corrosive sublimate and hydrochloric acid, which in the first instance yields the pure muriate of the base $As(CH_3)_2Cl$, in the form of a liquid volatile above 100° into vapours which take fire spontaneously in air. From this chloride of kakodyle the pure oxide is obtained by distillation with caustic potash. The pure oxide emits no fumes; its specific gravity is 1·462; it boils near 150°. A mixture of its vapour with air detonates at 50° C. From the chloride again, Bunsen obtained the free radical *kakodyle*, $(AsC_2H_6)_2$, by treatment with metallic zinc in a special apparatus, so constructed that all the several operations involved could be carried out without bringing the contents in contact with air,—a necessary precaution, because kakodyle is a liquid which takes fire in air spontaneously even at ordinary temperatures. Pure kakodyle is a heavy colourless liquid boiling at about 170° C., and freezing at − 6°. When exposed to oxygen or chlorine it suffers destructive combustion; but on slow access of air it is oxidized into its oxide, $(AsC_2H_6)_2O$, and kakodylic acid; with chlorine water it unites into the chloride which it came from; it also unites directly with sulphur and other elements; in short, it is exactly to kakodyle compounds what potassium is to potash and potash salts, "a true organic element," as Bunsen himself put it. This discovery of Bunsen's was greeted with an enthusiasm which it is difficult in these days to realize. With us now, a radical is intrinsically a fiction; it was different in 1842. By the isolation of kakodyle the "radical" notion suddenly rose from an unproved hypothesis to the rank of a theory based on experiment. Still, however much our theoretical notions may shift, Bunsen's research will stand as a piece of monumental scientific work.

Kakodylic acid, $As . O . (CH_3)_2 . OH$, is most conveniently prepared from the oxide by addition of water and oxide of mercury,—$H_2O + 2HgO$ supplying the $H_2 + O_3$ required for $1(AsC_2H_6)_2O$. This is a crystalline monobasic acid, soluble in water. Unlike the kakodylides of the As . X_3 type, it has no smell, and is no very violent poison. It takes six grains of it to kill a rabbit.

Metallic Methides.—Examples of these are—$Sb(CH_3)_3$; $Sb(CH_3)_5$; $Mg(CH_3)_2$; $Zn(CH_3)_2$; $Pb(CH_3)_4$; $Al(CH_3)_3$; $Sn(CH_3)_4$. To give an idea of the chemical character of this interesting class of bodies we choose *zinc-methyl* as a representative example, and state briefly the chief points of its chemical history. This body was discovered by Frankland in 1849. It is prepared by boiling iodide of methyl over granulated zinc in a flask connected with an inverted condenser, and so contrived otherwise that the contents are protected against access of moisture and oxygen. Under these circumstances the two ingredients gradually unite into a non-volatile and solid compound $IZn . (CH_3)$. When this body is heated with more of iodide of methyl, it undergoes decomposition, with formation of iodide of zinc and of dimethyl gas, $I—Zn—CH_3 + CH_3I = ZnI_2 + (CH_3)_2$, which reaction to some extent takes place unavoidably in the preparation of the zinc salt, however great an excess of metal may be taken. What survives needs only to be subjected to dry distillation (in the absence of air) to yield a distillate of zinc-methyl:—

$$2I—Zn—CH_3 = ZnI_2 + Zn(CH_3)_2.$$

Zinc-methyl is a colourless liquid of 1·386 specific gravity at 10°·5, which boils at 46° C.; in contact with air it takes fire. Water decomposes it at once into hydrate of oxide of zinc and marsh gas, $Zn(CH_3)_2 = Zn(OH)_2 + 2CH_3H$. Of other reactions the following may be named. (1) When digested with sodium, it yields a precipitate of metallic zinc, and a double compound of itself and sodium-methyl. This latter unites readily with carbonic acid into acetate of soda, $NaCH_3 + CO_2 = CH_3{-}CO{-}ONa$ (Wanklyn). (2) With chloride of acetyl it forms acetone, $Zn(CH_3)_2 + 2CH_3 . CO . Cl = ZnCl_2 + 2CO(CH_3)_2$ (Freund). (3) Under somewhat different conditions, including the presence of an excess of $Zn(CH_3)_2$, a compound is produced which with water, yields tertiary butyl-alcohol (Boutlerow).

$$CO(CH_3)_2 + Zn(CH_3)_2 = C(CH_3)_3 . O . ZnCH_3 = A;$$
$$A + 2H . OH = Zn(OH)_2 + CH_4 + \underbrace{C(CH_3)_3 - OH}_{\text{Tertiary alcohol.}}$$

(W. D.)

METRONOME, an instrument for denoting the speed at which a musical composition is to be performed. Its invention is generally, but falsely, ascribed to Johann Nepomuk Maelzel, a native of Ratisbon (1772–1838). It consists of a pendulum swung on a pivot; below the pivot is a fixed weight, and above it is a sliding weight that regulates the velocity of the oscillations by the greater or less distance from the pivot to which it is adjusted. The silent metronome is impelled by the touch, and ceases to beat when this impulse dies; it has a scale of numbers marked on the pendulum, and the upper part of the sliding weight is placed under that number which is to indicate the quickness of a stated note, as M.M. (Maelzel's Metronome) ♩ = 60, or ♩ = 72 or ♪ = 108, or the like. The number 60 implies a second of time for each single oscillation of the pendulum,—numbers lower than this denoting slower, and higher numbers quicker beats. The scale at first extended from 50 to 160, but now ranges from 40 to 208. A more complicated metronome is impelled by clock-work, makes a ticking sound at each beat, and continues its action till the works run down; a still more intricate machine has also a bell which is struck at the first of any number of beats willed by the person who regulates it, and so signifies the accent as well as the time.

The earliest instrument of the kind, a weighted pendulum of variable length, is described in a paper by Étienne Loulié (Paris, 1696; Amsterdam, 1698). Attempts were also made by Enbrayg (1732) and Gabory (1771). Harrison, who gained the prize awarded by the English Government for his chronometer, published a description of an instrument for the purpose in 1775. Davaux (1784), Pelletier, Abel Burja (1790), and Weiske (also 1790) described their various experiments for measuring musical time. In 1813 Gottfried Weber, the composer, theorist, and essayist, proposed a weighted ribbon graduated by inches or smaller divisions, which might be held or otherwise fixed at any desired length, and would infallibly oscillate at the same speed so long as the impulse lasted; this, the simplest, is also the surest, the most enduring, the most portable, and the cheapest invention that has come before the world, and one can but wonder that it has not been universally accepted. Stöckel and Zmeskall produced each an instrument; and Maelzel made some slight modification of that by the former, about the end of 1812, which he announced as a new invention of his own, and exhibited from city to city on the Continent. It was, as nearly as can be ascertained, in 1812 that Winkel, a mechanician of Amsterdam, devised a plan for reducing the inconvenient length of all existing instruments, on the principle of the double pendulum, rocking on both sides of a centre and balanced by a fixed and a variable weight. He spent three years in completing it, and it is described and commended in the *Report of the Netherlands Academy of Sciences*, August 14, 1815. Maelzel thereupon went to Amsterdam, saw Winkel and inspected his invention, and, recognizing its great superiority to what he called his own, offered to buy all right and title to it. Winkel refused, and so Maelzel constructed a copy of the instrument, to which he added nothing but the scale of numbers, took this copy to Paris, obtained a patent for it, and in 1816 established there, in his own name, a manufactory for metronomes. When the impostor revisited Amsterdam, the inventor instituted proceedings against him for his piracy, and the Academy of Sciences decided in Winkel's favour, declaring that the graduated scale was the only point in which the instrument of Maelzel differed from his. Maelzel's scale was needlessly and arbitrarily complicated, proceeding by twos from 40 to 60, by threes from 60 to 72, by fours from 72 to 120, by sixes from 120 to 144, and by eights from 144 to 208. Dr Crotch constructed a time-measurer, and Henry Smart (the violinist, and father of the composer of the same name) made another in 1821, both before that received as Maelzel's was known in England. In 1882 James Mitchell, a Scotsman, made an ingenious amplification of the Maelzel clock-work, reducing to mechanical demonstration what formerly rested wholly on the feeling of the performer. Although "Maelzel's metronome" has universal acceptance, the silent metronome and still more Weber's graduated ribbon are greatly to be preferred, for the clock-work of the other is liable to be out of order, and needs a nicety of regulation which is almost impossible; for instance, when Sir George Smart had to mark the traditional times of the several pieces in the Dettingen Te Deum, he tested them by twelve metronomes, no two of which beat together. The value of the machine is exaggerated, for no living performer could execute a piece in unvaried time throughout, and no student could practise under the tyranny of its beat; and conductors of music, nay, composers themselves, will give the same piece slightly slower or quicker on different occasions, according to the circumstances of performance.

METSU, Gabriel, a Dutch painter of celebrity (born in 1630, died after 1667), is one of the few artists of renown in Holland whose life has remained obscure. Houbraken, who eagerly collected anecdotes of painters in the 18th century, was unable to gather more from the gossip of his contemporaries than that, as early as 1658, Metsu, at the age of forty-three, submitted to a dangerous surgical operation. The inference drawn by superficial readers from this statement has been that death immediately ensued. A more careful perusal would have shown that Houbraken knew that Metsu had given lessons to De Musscher in 1665. Local records now reveal that Gabriel was the son of Jacques Metsu, who lived most of his days at Leyden, where he was three times married. The last of these marriages was celebrated in 1625, and Jacomma Garnijers, herself the widow of a painter, gave birth to Gabriel in 1630. Connected by both his parents with art, Metsu was probably taught first by his father and then by Gerard Dow. He probably finished his training under Rembrandt. So far back as 1648, but a few days earlier than Jan Steen, who is said to have painted his portrait, Metsu was registered in the painters' corporation at Leyden; and the books of the guild also tell us that he remained a member in 1649. In 1650 he ceased to subscribe, and works bearing his name and the date of 1653 give countenance to the belief that he had then settled at Amsterdam, where he continued his studies under Rembrandt. His companions at the time would naturally be De Hooch and Van der Meer, whose example he soon followed when it came to his turn to select the class of subjects for which his genius fitted him. Under the influence of Rembrandt he produced the Woman Taken in Adultery, a large picture with the date of 1653, in the Louvre, in which no one would suspect the painter of high life or taverns were it not that his name is written at full length on the canvas. The artist who thus repeated the gospel subjects familiar to

Flinck and Eeckhout was also acquainted with the Oriental wardrobe of Rembrandt, and ready to use it, like all his contemporaries. But he probably observed that sacred art was ill suited to his temper, or he found the field too strongly occupied, and happily for himself, as well as for his admirers, he turned to other subjects for which he was better fitted. We may doubt whether he tried the style of allegory as illustrated in a picture of Justice Protecting Virtue and Chastising Vice in the gallery of the Hague. There is every reason to think that this rough and frosty composition was wrought by quite another master. What Metsu undertook and carried out from the first with surprising success was the low life of the market and tavern, contrasted with wonderful versatility by incidents of high life and the drawing-room. In each of these spheres he combined humour with expression, a keen appreciation of nature with feeling, and breadth with delicacy of touch, unsurpassed by any of his contemporaries. In no single instance do the artistic lessons of Rembrandt appear to have been lost upon him. The same principles of light and shade which had marked his school-work in the Woman Taken in Adultery were applied to subjects of quite a different kind. A group in a drawing-room, a series of groups in the market-place, a single figure in the gloom of a tavern or parlour, was treated with the utmost felicity by fit concentration and gradation of light, a warm flush of tone pervaded every part, and, with that, the study of texture in stuffs was carried as far as it had been by Terburg or Dow, if not with the finish or the *brio* of De Hooch. Metsu's pictures are all in such admirable keeping, and so warm and harmonious in his middle or so cool and harmonious in his closing time, that they always make a pleasing impression. They are more subtle in modulation than Dow's, more spirited and forcible in touch than Terburg's; and, if Terburg may of right claim to have first painted the true satin robe, he never painted it more softly or with more judgment as to colour than Metsu.

That Metsu married and became a citizen of Amsterdam in 1659 would only prove that his residence in the commercial capital of the Netherlands was later than historians have generally assumed. But there is no reason to think that Metsu claimed his citizenship at once. The privileges of a burgess were given in exchange for a payment of dues, and these painters had various ways of avoiding unless they married. One of the best pictures of Metsu's manhood is the Market-place of Amsterdam, at the Louvre, respecting which it is difficult to distribute praise in fair proportions, so excellent are the various parts, the characteristic movement and action of the *dramatis personæ*, the selection of faces, the expression and the gesture, and the texture of the things depicted. A tin can in the arm of a cook is a marvel of imitation, but the cook's face is also a marvel of expression. Equally fine, though earlier, are the Sportsman (dated 1661) and the Tavern (also 1661) at the Hague and Dresden Museums, and the Game-Dealer's Shop, also at Dresden, with the painter's signature and 1662.

Metsu is one of the painters of whose skill Holland still preserves examples, yet whose best pictures are either in England or in France or in the galleries of Germany. The value of his works is large, and at the Pommersfelden sale in 1867 the Jealous Husband Dictating his Wife's Letters, though but one of several replicas, was bought by Lord Hertford for little short of £2000, while for the Ride of the Prince of Orange, in the Gsell collection at Vienna, £3000 was paid by Baron Rothschild in 1873. (J. A. C.)

METTERNICH, Clemens Wenzeslaus, Prince (1773–1859), first minister of Austria from 1809 to 1848, was the son of a Rhenish nobleman employed in high office by the Austrian court. He was born at Coblentz in 1773. At the age of fifteen he entered the university of Strasburg. The French Revolution was then beginning. Everywhere the spirit of hope gave to men's language an exaltation and a confidence hardly known at any other epoch. But the darker reality soon came into view. Metternich was a witness of the riot in which the town-hall of Strasburg was pillaged by a drunken mob; his tutor subsequently became a member of the revolutionary tribunal in Alsace. If we are to trust to Metternich's own account of the formation of his opinions, the hatred of innovation, which was the ruling principle of his later life, arose from his experience of the terrible results which followed at this time from the victory of so-called liberal ideas. But in reality Metternich was an aristocrat and a conservative by birth and nature. His sentiment in things political was that of a member of a refined and exclusive society which trusts to no intelligence but its own, and hardly sympathizes with larger interests. The aggressions and violence of the Revolution from 1789 to 1799 gave Metternich an historical basis for his political theories, but the instinctive preferences of his own mind were the same from first to last. He began life as a young man of fashion and gallantry. His marriage in 1795 with the Princess Kaunitz, a granddaughter of the famous minister, fixed him in the highest circle of Austrian nobility. His first contact with the great political world was at the congress of Rastadt in 1798, where, under the auspices of the victorious French republic, arrangements were made for compensating the German princes and nobles whose possessions on the left bank of the Rhine had been ceded to France by the peace of Campo Formio. Metternich was the accredited agent of a group of Westphalian nobles; his private letters give a vivid picture of the rough and uncourtly diplomatists who had succeeded to the polished servants of the old French monarchy. In 1801 Metternich was appointed Austrian ambassador at Dresden, and in 1803 he was promoted to Berlin; but he had hardly become as yet a prominent man in Europe. His stay at Berlin was the turning-point of his life. The war of the third coalition was impending. Austria united with England and Russia against Napoleon, and the task of the youthful ambassador was to win over the court of Berlin to the cause of the allies. Metternich seems to have done all that it was possible for him to do; but Prussia persisted in its neutrality. The earnestness with which Metternich had worked against France did not prevent him from remaining on the friendliest terms with M. Laforest, the French ambassador at Berlin; and so agreeable an account of him was transmitted to Paris by his rival that, at the close of the conflict, Napoleon himself requested that Metternich might henceforward represent Austria at the Tuileries. Metternich was accordingly sent to Paris in 1806. This was the beginning of the period when Austria, humbled but not exhausted by the blow of Austerlitz and by the losses accompanying the peace of Pressburg, determined, under the leadership of Count Stadion, to prepare for another war on a greater scale. But the sudden overthrow of Prussia, and the alliance between France and Russia which was made at Tilsit in 1807, added immeasurably to the difficulties of the court of Vienna. It became clear that Napoleon was intending to dismember Turkey, and to gain for himself some part of the spoils of the Ottoman empire. Metternich's advice was that Austria should endeavour to detach the czar from the French alliance, and by this means frustrate the plan of partition; but, should Russia hold fast to Napoleon, that Austria itself should unite with the two aggressors, and secure its share of Turkey. Oriental affairs, however, fell into the background, and in the summer of 1808 Metternich was convinced that Napoleon was intending to attack Austria, though not immediately. He warmly supported Count Stadion's policy in raising the forces of Austria to the highest strength; and, although he did not share the minister's hopes in a