OBITUARY NOTICE.

ARTHUR LAPWORTH.

1872—1941.

ARTHUR LAPWORTH was born on October 10th, 1872, at Galashiels; his father was Charles Lapworth (F.R.S., 1888, Royal Medallist, 1891), the eminent first Professor of Geology in the University of Birmingham, who was a pioneer in laying the foundations of stratigraphy. After early education at St. Andrews and at King Edward's School, Birmingham, he graduated at Mason College and, as an 1851 Exhibitioner (1893—95), proceeded to the City and Guilds of London Institute, where the presiding genius was H. E. Armstrong. However, Lapworth came more directly under the care of F. S. Kipping, who was at that time in charge of the main organic laboratory.

Professor Kipping writes :

" From the very first it was obvious that Lapworth had the experimental skill, as well as the powers of acute observation and sound deduction which would ensure his success in scientific work, and that his vivid imagination and high intellect would take him far in his profession. Any one who made Lapworth's acquaintance could not fail to wish for closer ties, and although he was considerably my junior in age we soon became fast friends; perhaps it would be truer to say that our relationship, even in those early days, was rather that of congenial brothers. He became a frequent visitor at our house in South Kensington, where he often met Pope, Forster, and other workers in Armstrong's laboratories, and my wife soon shared with me the great pleasure of his friendship. During one vacation when he had made no holiday plans, we asked him to stay with us at Bridgwater : here it was that he met his future wife, Kathleen Holland, with whom during forty years he spent the rest of his life in peaceful and loving marital harmony."

To this may be added that Kathleen was the younger sister of Mrs. Kipping and of Mrs. W. H. Perkin; thus Mrs. Holland was the mother-in-law of three distinguished chemists and Fellows of the Royal Society.

His postgraduate course at the " Central " included crystallography under the late Sir Henry Miers and following this he worked with Armstrong on the sulphonation of ethers of β-naphthol and with Kipping on derivatives of camphor and camphene. So began two of his main interests in later research, the chemistry of camphor and the mechanism of aromatic substitution. His D.Sc. thesis,* submitted at the age of twenty-three, on the naphthalene topic was the occasion for a characteristic display of courageous independence. He refused to alter some sections of the theoretical treatment which his formidable professor had criticised.

Lapworth's first post (1895) was that of Demonstrator in Collie's laboratory at the School of Pharmacy in Bloomsbury. One joint paper (*J.*, 1897, **71**, 838) on picoline derivatives from this period bears the Collie stamp. In 1900 he went to the Goldsmiths' Company's Institute at New Cross as Head of the Chemistry Department (1906, Goldsmiths' College) and in 1909 became Senior Lecturer in Inorganic and Physical Chemistry and Schunck Fellow at the University of Manchester. Four years later he succeeded W. H. Perkin, jun., in the Chair of Organic Chemistry and in 1922 became Sir Samuel Hall Professor (primarily responsible for physical and inorganic chemistry) and Director of the Laboratories. The writer, first as a Junior Demonstrator and, after an interval of years, as Professor of Organic Chemistry, had the inestimable privilege of his friendship and collaboration. At lunch in the refectory and at many other times we exchanged ideas, often expressed on the back of envelopes by what Armstrong was pleased to call " noughts and crosses ". During this latter period Mrs. Lapworth acted as his secretary in the department.

His last appointment demonstrates Lapworth's remarkable breadth and versatility; very few men in the twentieth century would be thought competent to hold in succession chairs of organic and physical chemistry. He retired in 1935 and was appointed Professor Emeritus. He was elected F.R.S. in 1910, served on the Council (1927—29), received the Davy Medal in 1931, and was an honorary LL.D. of Birmingham and of St. Andrews universities. These distinctions are mentioned with some uneasiness; high as they are they afford no measure of the achievement of a man whose influence on chemical philosophy was outstanding.

His modest disposition did not bring him into the limelight; he was not a showman, tending rather to disparage his wares; he made no dramatic discoveries such as to catch the public eye;

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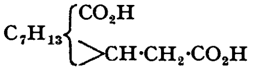
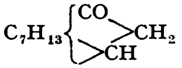
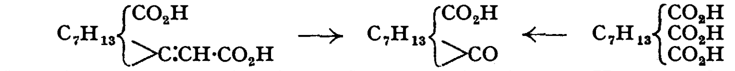
* " Sulphonic acids of betamethoxy- and betaethoxy-naphthalene." Thesis for D.Sc. (London), April, 1895.

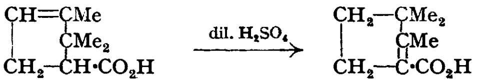
he never flogged a dead horse and even left some promising live ones to fend for themselves. He investigated in order to learn something, to educate himself, and not with the primary object of producing elegant and finished scientific memoirs, though he did indeed leave many such on record. Much of his work seems, therefore, incomplete, and his output of over a hundred papers was, judged by some standards, relatively small. Yet the power of his genius triumphed and it is now possible to see how his ideas, always many years ahead of those of his contemporaries, played a leading part in the contribution which organic chemists have made to the revolution in chemical thought. The electronic theory of valency has made it possible to give a measure of precision to many of the suggestions he advanced on an electrochemical basis, but Lapworth's preparation of the ground was essential. During many years little attention was paid to his views; now they are the commonplaces of the textbooks.

One of Lapworth's first major interests was the constitution of camphor and the way he attacked the problem was very significant. There are quite a number of ordinary papers on the detailed chemistry of derivatives; just the kind of thing that many workers in the field could, and did, produce. Certainly some of this material was of great importance and demonstrated his skill as an experimentalist, in particular his study of homocamphoric acid (*J.*, 1899, **75**, 986; 1900, **77**, 446, 1053) forged a vital link in the chain of evidence. In this investigation he showed that homocamphoric acid can be degraded to dehydrohomocamphoric acid and then to camphononic acid, which must be a *cyclo*pentane derivative because it could be synthesised by ketonisation of homocamphoronic acid. But his characteristic contribution was an idea—an interpretation of the chemistry of camphor which reconciled apparently conflicting data (*Brit. Assoc. Rep.*, Sec. B, Bradford, 1900). In other words he saw through the mist and by recognising the occurrence of a remarkable molecular rearrangement in the formation of *iso*lauronolic acid removed the chief stumbling block to the general acceptance of Bredt's camphor formula.


Homocamphoric acid.

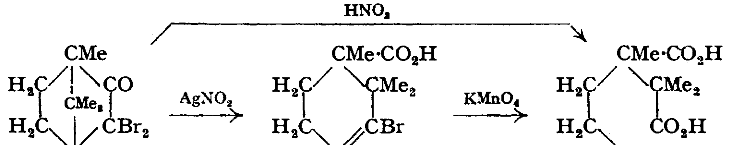

Camphor.


Dehydrohomocamphoric acid. Camphononic acid. Homocamphoronic acid.


Lauronolic acid. *iso*Lauronolic acid.

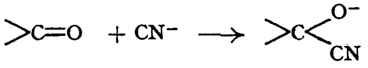
The postulated intramolecular change was compared by Lapworth with the pinacol–pinacolone rearrangement and a similar explanation was also applied to the change of α- to β-campholenic acid, which was another source of confusion.

Homocamphoronic acid (III) itself and the stages of its production from αα-dibromocamphor (I) gave a great deal of trouble, as may well be understood when the direct formation of the acid by oxidation of (I) with nitric acid is considered (*J.*, 1899, **75**, 986). A carbon atom seems to get out of place.


(I.) (II.) (III.)

It was shown, however, that Forster's bromocamphorenic acid (II) is probably an intermediate product, and the very remarkable molecular rearrangement, (I) ⟶ (II), was suggested as the result of an extensive series of investigations (*J.*, 1899, **75**, 1134; 1900, **77**, 309, 446; 1902, **81**, 17). Lapworth carried these out in a systematic fashion by the careful study of the properties and reactions of the substances mentioned and, in addition, of camphonic acid, camphononic acid, and various bromo-lactones. It does not seem to have occurred to him to attempt the synthesis of homocamphoronic acid, although that is perhaps due to the fact that the structures became clear only towards the end of a prolonged study.

The examples cited of the mobility of the camphor complex could be supplemented by many others and there is no doubt that the general acceptance of Bredt's formula owed as much to Lapworth's searching analysis as to the eventual synthesis of camphoric acid. Much later he prepared homocamphor (*J.*, 1920, **117**, 743), but the connecting link with later activities was perhaps his work on cyanocamphor and homocamphoric acid (*J.*, 1900, **77**, 1053). He was led to consider the problem of the addition of hydrocyanic acid to carbon compounds more generally and especially to the αβ-unsaturated ketones and the ketones and aldehydes themselves (*J.*, 1903, **83**, 995; *Proc.*, 1904, **20**, 245; *J.*, 1904, **85**, 1206—1214, 1355; 1906, **89**, 1819, 1869; 1907, **91**, 694, 977; 1910, **97**, 11; *Proc.*, 1911, **27**, 240; *J.*, 1911, **99**, 1877; 1928, 2533; 1930, 1976). The studies ranged from observations of the β-addition of cyano-groups to αβ-unsaturated ketones such as mesityl oxide, benzylideneacetone, carvone, and pulegone to the later, careful examination of the conditions of formation and the stability of cyanohydrins. There is little doubt that reflection on the mechanism of these reactions played an important part in directing his attention to the principle of " alternate polarities ". From the first he adopted ionic mechanisms, and a good illustration of his ideas is seen in the view he put forward of the course of the formation of benzoin from benzaldehyde (*J.*, 1907, **91**, 694). The production of a cyanohydrin was regarded by Lapworth as involving the direct attack of cyanidion on a carbonyl group :



$$>C{=}O + CN^- \longrightarrow >C\begin{array}{l}O^-\\CN\end{array}$$

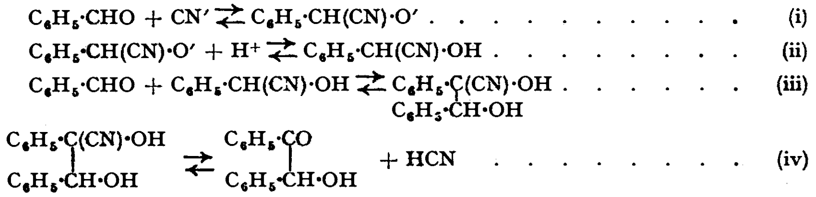
This he made very probable by a study of the effect of catalytic agents on the velocity of the addition (*J.*, 1903, **83**, 995) and by showing that the cyanohydrins are complex acids of which he was able to prepare the salts (*J.*, 1904, **85**, 1206). Thus by the action of potassium cyanide on benzaldehyde and camphorquinone he obtained crystalline potassium salts of the cyanohydrins. This view was confirmed by much subsequent research by Lapworth himself, by Bredt, and by Goldschmidt.

The second stage in the formation of a cyanohydrin is the decomposition of water, or an alcohol or acid, by the complex ion :

$$>C\begin{array}{l}O^-\\CN\end{array} + H_2O \longrightarrow >C\begin{array}{l}OH\\CN\end{array} + OH^-$$

He early recognised that these processes must be reversible and that normally an equilibrium will be set up. The theory explained very well why cyanohydrins are so advantageously prepared by the action of pure hydrocyanic acid on a ketone in the (necessary) presence of a small proportion of an alkaline catalyst, which may be potassium cyanide, or may even be derived from the glass container.

To complete the scheme of the benzoin synthesis it was assumed that benzaldehyde undergoes an aldol-like synthesis with mandelonitrile, and that the cyanohydrin of benzoin is relatively unstable. This was probable on theoretical grounds, and from analogies, but it was also experimentally demonstrated. The complete scheme was (*J.*, 1907, **91**, 694) :



$$C_6H_5\cdot CHO + CN' \rightleftarrows C_6H_5\cdot CH(CN)\cdot O' \quad \ldots\ldots\ldots\ldots \quad (i)$$

$$C_6H_5\cdot CH(CN)\cdot O' + H^+ \rightleftarrows C_6H_5\cdot CH(CN)\cdot OH \quad \ldots\ldots\ldots \quad (ii)$$

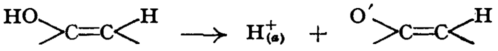
$$C_6H_5\cdot CHO + C_6H_5\cdot CH(CN)\cdot OH \rightleftarrows \begin{array}{l}C_6H_5\cdot C(CN)\cdot OH\\ \quad |\\ C_6H_5\cdot CH\cdot OH\end{array} \quad \ldots\ldots \quad (iii)$$

$$\begin{array}{l}C_6H_5\cdot C(CN)\cdot OH\\ \quad |\\ C_6H_5\cdot CH\cdot OH\end{array} \rightleftarrows \begin{array}{l}C_6H_5\cdot CO\\ \quad |\\ C_6H_5\cdot CH\cdot OH\end{array} + HCN \quad \ldots\ldots\ldots \quad (iv)$$

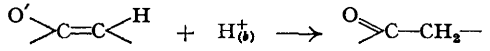
It will be noticed that Lapworth postulated reversibility of each stage. The theory has stood the test of forty years and is generally accepted as correct : undoubtedly it represented a landmark in the progress of our understanding of the course of chemical change.

Another outcome of the early camphor period was the use made of optical activity to study the phenomena of desmotropic, or tautomeric, change (*J.*, 1902, **81**, 1491, 1499, 1508; 1903, **83**, 114; 1904, **85**, 46; 1911, **99**, 1785). From the first Lapworth regarded these processes from the ionic point of view first advanced by Brühl in 1899, but in a less explicit form. He, however, greatly extended the conception and supported it by many experimental researches carried on throughout his active career.

Mechanisms were invariably adopted which stressed the fact that the ions, particularly hydrogen ions, must often be regarded as coming in from outside and also as leaving for an unknown, and possibly remote, destination. Thus in keto-enol tautomerism catalysed by acids we have :



$$\mathrm{HO}\!>\!C{=}C\!<\!\mathrm{H} \longrightarrow \mathrm{H}^{+}_{(a)} + \mathrm{O'}\!>\!C{=}C\!<\!\mathrm{H} \quad \ldots\ldots \quad \text{(i)}$$



$$\mathrm{O'}\!>\!C{=}C\!<\!\mathrm{H} + \mathrm{H}^{+}_{(b)} \longrightarrow \mathrm{O}\!\gg\!C{-}CH_2{-} \quad \ldots\ldots \quad \text{(ii)}$$

where the two protons *a* and *b* are not the same. Although these views, and perhaps some others that he advocated, were not completely novel, Lapworth made a better combination of them than any other chemist. His consistency and theoretical insight made a great impression on his contemporaries and exercised a powerful influence on the development of organic chemical theory. At a later stage he became interested in the mechanism of esterification and hydrolysis (*Proc.*, 1908, **24**, 100, 152, 153; *J.*, 1908, **93**, 2163, 2187; *Proc.*, 1909, **25**, 20; *J.*, 1910, **97**, 19; 1911, **99**, 917, 1417, 1427, 2242; 1912, **101**, 2249; 1913, **103**, 252; *Proc.*, 1914, **30**, 141; *J.*, 1915, **107**, 857; 1922, **121**, 76). Here again the emphasis was on hydrogen ion catalysis and the theory of acids and complex ions in various media. The researches were developed with the refinements of physico-chemical techniques and cannot usefully be summarised in the course of a short discussion. Many aspects of the work were unfinished and inconclusive but, taken as a whole, it must be admitted that this series of memoirs made an essential contribution to a subject which has excited great interest, and has of course been advanced by many other workers.

Another penetrating suggestion made by Lapworth concerned the mechanism of the bromination of ketones; the case chosen for study was acetone. The rate of bromination was found to be independent of the concentration of bromine and the process was catalysed by acids.

Lapworth suggested that the rate-determining change is the formation of enol from the acetone and that this is immediately brominated. The reaction is therefore autocatalytic due to the accumulation of hydrogen bromide. This view is accepted to-day for the acid-catalysed reaction, but other ions than hydrogen ions play a part and the complexity of the system is illustrated by H. M. Dawson's subsequent examination of the iodination of acetone. Anionotropic as well as prototropic reactions are in evidence. Considering the date (1913) of Lapworth's work (*Proc.*, 1913, **29**, 283) the advance he made was remarkable.

The conception of very rapid bromination of an enol was later utilised by K. H. Meyer for the analysis of mixtures of enols and ketones, for example, ethyl acetoacetate, under various circumstances. Lapworth often told the writer that he ought to have made this ingenious but obvious application. It is, however, doubtful whether full enolisation occurs, and it is not necessary to postulate it. Thus Leuchs has shown that an optically active ketone, the enol of which must be optically inactive, can be brominated without loss of activity. This recalls the observation of Kuhn and Albrecht that optically active *sec.*-nitrobutane yields an optically active sodium salt. Many other examples of Lapworth's concern with reaction mechanisms could be cited, including his early generalisations of the form of intramolecular changes (*Proc.*, 1895, **11**, 49; *J.*, 1898, **73**, 445; *Proc.*, 1901, **17**, 2; *J.*, 1901, **79**, 1265) and an examination of the synthesis of acetoacetic ester (*Proc.*, 1903, **19**, 189). Moreover he made kinetic studies of many reactions other than those mentioned and his work on the rate of oximation and the properties of oximes (*J.*, 1902, **81**, 549; 1907, **91**, 1133; 1908, **93**, 85) may be given in illustration.

Lapworth discovered many new reactions and transformations of which the following are among the more interesting.

Possibly his investigations of the addition of hydrogen cyanide to unsaturated ketones suggested that the quality of reactivity of the carbon of a carbonyl group can be transmitted to the β-carbon of an αβ-unsaturated ketone. If so, he may have argued, a carbonyl might activate a methylene group through a double bond. At any rate, in 1900 he made an experiment that must have had some such theoretical background.

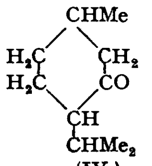
He found (*Proc.*, 1900, **16**, 132) that ethyl crotonate condensed with ethyl oxalate in the presence of sodium ethoxide as follows :

$$CO_2Et{\cdot}CO_2Et + CH_3{\cdot}CH{:}CH{\cdot}CO_2Et \longrightarrow CO_2Et{\cdot}CO{\cdot}CH_2{\cdot}CH{:}CH{\cdot}CO_2Et$$

The constitution of the product has since been confirmed; this was necessary in view of the possibility of the double bond migration to the βγ-position, followed by oxylation in the α-position. An extension was made later (*J.*, 1923, **123**, 1325).

Lapworth and Wechsler (*J.*, 1907, **91**, 1919) noted an anomalous reaction of cyanodihydrocarvone with amyl nitrite in the presence of sodium ethoxide. Further experiments revealed an interesting scission of ketones containing the group $-CO-\overset{|}{C}H-$ under the same conditions. It may be assumed that a nitroso-derivative is first formed and that this adds the elements of alcohol to yield $-CO{\cdot}OEt + HON{:}C{<}$ (*J.*, 1908, **93**, 30).

Thus menthone (IV) yields (V) after hydrolysis of the product; pulegone (VI) gives (VII), the process involving the above-mentioned shift of a double bond. A simple model was provided (*J.*, 1911, **99**, 1882) by phenyl *iso*propyl ketone, $Ph{\cdot}CO{\cdot}CHMe_2$, which was found to be converted by amyl nitrite in alcoholic sodium ethoxide into benzoic ester, $Ph{\cdot}CO_2Et$, and acetoxime, $HON{=}CMe_2$. This reaction has been applied to cinchoninone and affords in this and other cases a useful resource for the ring-fission of ketones.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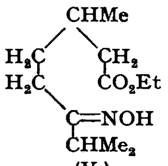
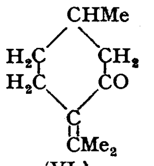
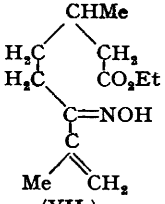
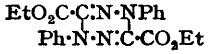

(V.)


(VI.)


(VII.)

Another degradation was discovered when bromine was allowed to act on ethyl benzeneazoacetoacetate, $CH_3{\cdot}CO{\cdot}CH(N_2Ph){\cdot}CO_2Et$, when the acetyl group was eliminated and a so-called hydrizino-derivative, $CBr({:}N{\cdot}NHPh){\cdot}CO_2Et$, was produced (*J.*, 1905, **87**, 1854). When treated with alkalis, two molecules condensed to give ethyl diphenyldihydrotetrazinedicarboxylate,



$$\begin{array}{l} EtO_2C{\cdot}C{:}N{\cdot}NPh \\ \quad Ph{\cdot}N{\cdot}N{:}C{\cdot}CO_2Et \end{array}$$

These novel types of substances have not received much subsequent attention.

An interesting paper on sulphonic esters (*J.*, 1912, **101**, 273) describes some new reactions based on the idea that esters and sulphonic esters tend to undergo scission at the dotted line: $R{\cdot}CO-\vdots-O-R'$, $R{\cdot}SO_2{\cdot}O-\vdots-R'$. It was found that olefins add the elements of sulphurous acid with the production of sulphonic acids (*J.*, 1925, **127**, 307). In the simplest case ethylene reacts with sodium hydrogen sulphite with formation of ethanesulphonic acid, which was isolated as the barium salt:

$$CH_2{:}CH_2 + NaHSO_3 \longrightarrow CH_3{\cdot}CH_2{\cdot}SO_3Na$$

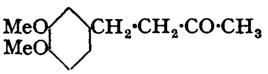
This reaction was rather unexpected; it underlines the abnormality of sulphur and recalls Posner's experiments on the addition of mercaptans to unsaturated substances.

At various times Lapworth paid considerable attention to improvements of preparative methods and to the prescription of satisfactory recipes. For example, he made really pure oleic acid (*Biochem. J.*, 1925, **19**, 7) and studied its quantitative oxidation to dihydroxystearic acid (*J.*, 1925, **127**, 1628, 1987). This is only one instance of his interest in the chemistry of the fats. He began work on sphingosine and cerebrone (*J.*, 1913, **103**, 1029) but never carried it far.

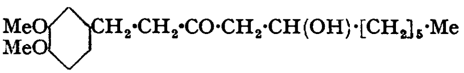
Other illustrations of the improvement of methods are the reductions of emulsified nitro-compounds (*J.*, 1921, **119**, 765, 768; 1925, **127**, 2970) whereby excellent yields of arylhydroxylamines were obtained, and contributions to *Organic Syntheses* (1927, **7**, 20; 1928, **8**, 99) based on his earlier work with McRae (*J.*, 1922, **121**, 1699, 2741). The details are characteristically elegant. An aldehyde such as benzaldehyde is brought into reaction with sodium cyanoacetate, previously made in the usual way; the addition of hydrocyanic acid and hydrolysis then afford a substituted succinic acid.

An unusual development for Lapworth was a study of natural products, in this case the pungent principles of ginger (*J.*, 1917, **111**, 77) and capsicum (*J.*, 1919, **115**, 1109). It is curious that E. K. Nelson, and also H. Nomura, published work on gingerol almost simultaneously with that of Lapworth, Pearson, and Royle. The work of Lapworth and his collaborators was the most comprehensive. The oleo-resin of Thresh, and of Garnett and Grier, methylated by means of methyl sulphate and alkali, yields a crystalline compound termed methylgingerol. This is decomposed by heat or alkali into methylzingerone, $C_{12}H_{16}O_3$, and aldehydes, of which the chief is *n*-heptaldehyde. Methylzingerone was proved by analysis and synthesis (*J.*, 1917,

111, 790) to be β-veratrylethyl methyl ketone (VIII) and the most plausible view of methylgingerol is expressed by the constitution (IX).



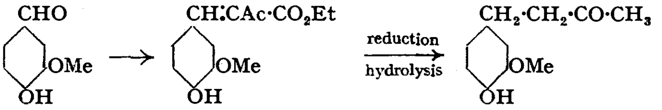
(VIII.)



(IX.)

Similarly the oleo-resin, before methylation, gave zingerone, $C_{11}H_{14}O_3$, which was proved by synthesis to be (X).

When, in the early Manchester days, one discussed synthetical projects with Lapworth, it was quite clear that he had some unusual way of deciding whether they would " go " or not. It turned out to be a scheme of alternating polarities in a chain of atoms, and the theory was published in 1920. Although somewhat hidden in the *Memoirs of the Manchester Literary and Philosophical Society* (lxiv, No. 3, 1), the paper evoked much interest, and not a little criticism. In later publications the theoretical basis was broadened and the principle developed with a conception of " virtual valencies " (*J.*, 1922, **121**, 416). Unfortunately this method of treatment was difficult to assimilate because of its form and, as the electronic interpretations, really equivalent to Lapworth's, were gradually adopted generally, this memoir of 1922 was almost forgotten.

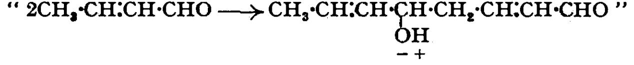


(X.)

Lapworth's main contribution to modern theory was his classification of reagents and his earlier work on reaction mechanisms, which were closely inter-related.

Starting from the two ionic types, he termed groups and molecular centres that exhibit reactive properties analogous to anions, *anionoid*, and those behaving like cations, *cationoid*. These expressions have exactly the same meaning as Ingold's *nucleophilic* and *electrophilic*. They implied electron donors, and electron acceptors, respectively. In regard to a few misconceptions, which arose in discussions, let Lapworth speak for himself (citations from *Mem. Manchester Lit. Phil. Soc., loc. cit.*). " The writer originally fell into the habit of labelling the atoms in reactive molecules with + and — signs as the result of his applications of the ionic theory to the reactions of carbon compounds and especially to those of ketones and allied carbonyl compounds. . . . It must be emphasised, however, that in attaching the + and — signs to the oxygen and carbon atoms no hypothesis is invoked, nor is it necessary, or even desirable, to assume that electrical charges are developed on these two atoms (except perhaps at the actual instant of chemical change). The signs are applied, in the first instance, merely as expressing the relative polar characters which the atoms seem to display at the instant of the chemical change in question." He clearly distinguished his views from the earlier theories of Fry and Vorländer which, more precisely in the case of Fry, did postulate actual alternate electric charges.

An example given was :



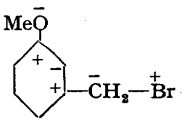
$$\text{“ }2\overset{-}{C}H_3\cdot\overset{+}{C}H{:}\overset{-}{C}H\cdot\overset{+}{C}H\overset{-}{O}\longrightarrow\overset{-}{C}H_3\cdot\overset{+}{C}H{:}\overset{-}{C}H\cdot\underset{\underset{-\ +}{OH}}{\overset{+}{C}}H\cdot CH_2\cdot\overset{+}{C}H{:}\overset{-}{C}H\cdot\overset{+}{C}H\overset{-}{O}\text{ ”}$$

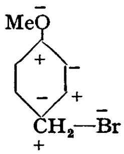
" It must now be evident from [corrected in reprints to *in*] the cases already dealt with that the whole order of alternating latent polarities is determined by the oxygen atom or atoms. . . . The extension of the influence of the directing, or *key-atom*, over a long range seems to require for its fullest display the presence of double bonds, and usually in conjugated positions, consequently the principle must find ample scope in the aromatic series where conjugation is the rule."

It was this aspect which was emphasised in the paper of 1922 (*J.*, 1922, **121**, 416) and the views there developed are, to all intents and purposes, identical with those advanced by the present writer starting from the conception of partial valencies. Both had some analogies with the systems of Thiele and of Flürscheim and in some applications gave identical results. There was seen to be divergence, however, in other important respects and the origin of these became clear with the development of translations into the terms of the electronic theory of valency.

The working hypothesis of " labelling " from a key-atom gave rise to some interesting experimental work and an early example is that of Lapworth and Shoesmith (*J.*, 1922, **121**, 1391) on the methoxybenzyl bromides.

Thus the *m*- and *p*-isomerides are labelled from oxygen as key-atom :





The behaviour of these substances was found to harmonise with that predicted from the figures. It was known that Br in, for example, $\overset{-}{O}{=}\overset{+}{C}{-}\overset{-}{Br}$ is very readily replaced by OH and that Br in $\overset{-}{O}{=}\underset{|}{\overset{+}{C}}{-}\underset{|}{\overset{-}{C}H}{-}\overset{+}{Br}$ is unusually readily replaced by H. *p*-Methoxybenzyl bromide was much more easily hydrolysed to the related alcohol than was *m*-methoxybenzyl bromide, and in reductions to the tolyl methyl ethers, the *m*-isomeride was the more reactive.

Nowadays the properties of the *p*-derivative can be readily interpreted on a more precise electronic basis, but the *m*-derivative would be regarded as a benzyl bromide, lacking the special constitutive features of the *p*-type, and differing from benzyl bromide itself only as the result of the general electrical effect of the methoxy-group. In other words, it is the *p*-derivative that exhibits exceptional behaviour, and a comparison of benzyl bromide and *m*-methoxybenzyl bromide is required in order to estimate the significance of the contrast to which Lapworth and Shoesmith drew attention.

About this period (1922—26) an active controversy arose (cf. *J.*, 1925, **127**, 1742); this consumed much time and effort but need not be described in detail. Lapworth himself would be the last to desire these ephemeral writings to be resuscitated on account of their purely historical interest. It had at least one useful result in that the theory was more quickly moulded into its present form.

The chief subsequent events have arisen from the applications of quantum mechanics to organic chemical problems. These have provided a new calculus for the electronic theory of valency but have not rendered the older qualitative approach obsolete.

Lapworth's last scientific paper (*J.*, 1931, 1959) was most happily a collaborative effort with Professor C. K. Ingold. It was concerned with the problem of *m*-nitration of toluene. Competitive nitrations of toluene and benzene show that toluene is far more readily attacked than benzene. But in the nitration of toluene, only 4·4% of the *m*-derivative is produced. The question arises—does the methyl group activate the *m*-position, relative to the reactivity of benzene ? Careful experiments showed that this is indeed the case, the disparity of toluene and benzene reactivity being sufficient.

There is little doubt that Lapworth would have continued to shed light on these and similar problems but unfortunately signs of his illness made their appearance early in the third decade of the century. He continued for some years to inspire his colleagues and collaborators by discussion and correspondence. Indeed it is true to say that throughout his life, though his publications are highly important, his generous help to others had an almost equal, if not greater, influence on the progress of science.

The world-wide recognition of Lapworth's genius and his abiding scientific reputation increases with the passage of time. It is now seen that his insight into chemical mechanisms, and his insistence on the electrochemical point of view at the molecular level, forged a necessary link in the chain of theory which now connects the most diverse phenomena.

In the laboratory one of his students, Dr. G. N. Burkhardt, gives the following picture. " He was skilful in devising and using the simple methods which he always preferred and, with a home-made cigarette in one corner of his mouth, and his head on one side, he would attack a new substance with reagents and a set of test-tubes. Using traces of material and a number of uncommon devices, he would find as much in a few minutes as might take hours to establish on a larger scale with more elaborate technique. As a teacher, lecturing on three main branches of chemistry in succession, he concerned himself to an unusual degree with the exposition of ideas, methods, and general principles, so that his lectures were most stimulating and valuable to his better students, though they could be the despair of those whose tastes or abilities required only the easy catalogue of facts."

In his dealings with his fellow men he was selfless, generous to a fault, and completely straightforward and sincere. His scientific work occasionally brought him into controversy with exponents of older views, but this was always conducted with great dignity and the most careful choice of words. Incidentally he possessed an enviable command of language especially noticed in his writing, and a pretty and sometimes caustic wit, entirely free from any suspicion of malice. As administrator of his department and laboratory he showed firmness and wisdom, but this was not his real *métier* and it is a pity that a sense of duty compelled him to undertake responsibilities which turned out to last far too long. As already mentioned, the valuable help of Mrs. Lapworth lightened the load of routine for several years. The loyalty with which Lapworth was served and the undying devotion of all those who collaborated with him whether in teaching or research are the best testimony to his professional work and the University of Manchester owes much to his encouragement of young men of promise and to his guidance of the School of Chemistry during critical years.

A sensitive soul, always sparkling with vitality, all-embracing in his curiosity and interest, it is natural that he had many hobbies.

His father was a pianist and his mother and sister were accomplished singers. He himself played the violin and 'cello and was a lover of music, with sound and individual taste and a wide knowledge of the classics. He had little use for the modern forms. At New Cross he took part, as violinist, in chamber music and played in the College orchestra. When he came to Manchester Perkin asked him to share in his famous musical parties but there were too many violinists and Lapworth learned the viola. For many years he served on the Council of the Royal Manchester College of Music. He was a good dancer, was fond of the theatre, of films, radio, and the gramophone, and, in my time, he was a voracious reader of thrillers. Carpentry and microscopy were just two of his pursuits, and outside his chemistry his main scientific interests were astronomy, geology, and botany. He was an authority on British mosses and made a fine collection of them.

Holidays were spent in mountaineering and later in golfing and fishing. As a boy he started scrambling at St. Andrews and soon accompanied his father on geological expeditions to the mountains. At the age of eighteen he made a solitary ascent of the Petit Dent de Veisivi and later climbed Lliwedd and the Rosenlaui Engelhörner by several routes.

Much affected by the loss of his friend Humphrey Owen Jones and his wife on the Aiguille Blanche de Peteret, he never climbed again.

His fishing ground was chiefly the river Eden near Gosforth, and he was a member of the Yorkshire Anglers Club. Speaking of one of his friends he said : " The keenest angler I know—what a pity that he never catches fish ".

The outdoor life consorted well with his interest in nature, and it was K. J. P. Orton who introduced him to the study of birds. Orton, a recognised authority, was good with the field-glasses, but Lapworth's trained and sensitive ear enabled him to surpass his teacher in the recognition of birds by song. Birding with the Ortons was the *raison d'être* of many happy expeditions round Hayes Common, Keston, and in the Bangor district. Many years later the writer found in a St. Andrews " den " that Lapworth had not forgotten his craft.

The breadth of interest and joy in life which Lapworth showed in his recreations were characteristic of the man. In science, too, his temperament might have caused too wide a spread, but he was saved from this by self-discipline and by a dominant theoretical theme.

Lapworth's health, at least in later years, was never robust, and the exceptional strain of carrying the burden of the whole Department of Chemistry eventually broke it down. His long and distressing illness was borne with the greatest fortitude, but, until the very end, he never lost his interest and was able to enjoy the visits of his friends at intervals.

R. ROBINSON.