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GENETICS AND PLANT BREEDING *

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" All flesh is grass "—this is no less true of man as of other animals. From time immemorial man has obtained his food either immediately or ultimately from plants. Although gold and silver have come to mean wealth, only crops and cattle furnish that primary wealth that makes for happiness and contentment. The population of the world is increasing, and so is the standard of living. More and better food is necessary. This can be attained by increasing the area under crops, and by improving the facilities for growing them. If, added to this, the inherent quality of the seed —the basis of all crops—is also improved, the farmer will be in possession of wealth that does not depreciate with the vicissitudes of fortune. If each individual is to do this plant breeding for the grading up of superior seed it would be a costly venture. The State therefore steps in to do this for the cultivator. The production of better crops without additional expense to the grower being the simplest way of increasing agricultural wealth every progressive country now maintains centres of research for the solution of its crop breeding problems. Genetics is the science that helps us in crop-breeding. It deals with the laws of heredity—the transmission of characters from parent to offspring.

Plant breeding, although it existed as a nebulous art even in ancient times, took definite shape in Europe only by the 19th century, when a few discerning individuals like Shirref, Knight, Le Couteur and Vilmorin, hit upon single plant selection as a means of improving crop yields.

Increase in yields is possible in two ways, one by preventing loss by pests and diseases, and the other by securing a larger out-

turn per acre. This again is attainable either through better methods of cultivation or by a change in the heritable constitution of the plant itself. This latter is the work of the plant breeder. The breeder's role in the realm of living things is comparable to the inventor's in the realm of industry. In both new and improved forms replace the old, and make possible what was not possible before. On the protective side, the breeding of strains resistant to disease forms one of the major lines of work in the fight against pests and diseases. It is the object of this lecture to show how plant breeding, though still more an art than a science, is slowly raising itself with the aid of advances in genetics, cytology and physiology, to the status of a science.

It may be stated at the outset that the basic methods in plant breeding were discovered empirically and utilized long before genetics and cytology revealed their scientific foundations. Even now, after nearly forty years of progress in these two sciences, serious gaps exist in our knowledge of how exactly such economic characters as high yield, earliness, drought resistance and disease resistance behave in inheritance. In nearly every crop, a high yield is the chief, if not the sole aim. This yield, however, is merely the end-product of a long chain of inter-related processes taking place throughout the life of the plant. Strenuous attempts are being made to resolve this end effect into its components, but the progress so far has been rather slow. Our knowledge of the plant's life-processes, comprised under the term plant-physiology, is sufficient merely to indicate how profound our ignorance is even now. It merely shows, like a lighted match in a vast cavern, the immensity of darkness yet unlit.

Scientific training apart, the breeder must also have a genuine love of his work, a trained eye that is alive to even minute differences among the plants he works with, great patience and a delicate touch; for, work such as emasculating flowers and cross-pollination demands a high degree of manipulative skill.

Methods in Plant Breeding.—The practical methods are three, namely—introduction, selection, and hybridization. *Plant introduction:*—Potatoes were introduced into Europe in 1587 from South America. Cocoa, which also was known in Europe only by the 16th century, through the soldiers of Cortez from Mexico, has now made the wealth of the Gold Coast Colony in Africa. Para rubber (*Hevea braziliensis*) was introduced into the Old World, to start the great Empire Plantations of Ceylon, India, and Malaya, by Sir Henry Wickham in the 1870s from the Amazon valley, a

feat that is one of the high lights of adventure in the cause of commerce. As other instances, may be cited the successful introduction of wheat and sorghum into North America, of maize and tobacco into Africa, India and China, and of cinchona from Peru into India and the Far East. The influx of various temperate plants, like the cabbage, cauliflower, carrots and radish into the colder regions of India is yet another instance of successful introduction. *Selection*:—All plants have a certain uniformity. On scrutiny into this superficial uniformity, however, it is found that the individuals comprising the crop differ from one another in small but definite features. By picking out the most desirable individuals, and then multiplying their seed, an improved strain is obtained. By this method of plant selection outstanding achievements have often been attained. Thus Hallett, in the latter half of the 19th century, founded a new superior type of maize only by this method. " Chevallier " barley, for many years the best barley for making beer, was discovered in 1819 by sheer accident by a clergyman in Suffolk, the Rev. Dr. John Chevallier. The Gros Michel banana, that is now the backbone of the West Indian trade in bananas, was multiplied from a bud-sport in Mauritius. Under Napoleon's inspiration, the wild beet, *(Beta maritima)*, with its 5% sugar content was improved by the Vilmorins and the sucrose content increased up to 20 per cent.

In recent times and nearer home in Madras, we have as outstanding examples of varieties improved by selection, the paddy strain G. E. B. 24, the ragi strain E. C. 593, and the cotton strain Co. 2.

Going deeper into the methods of selection, we have first the age-old method of *Mass selection*—where a large number of individual plants possessing desirable features are selected, mixed and sown the next season. This process is repeated for a few more seasons until improvement in yield over the original sample is attained. We have next the method of *Single plant selection.* Here too the best looking plants are picked out, but the seed from each plant is kept separate and sown the next season separately. The subsequent progeny yields are recorded and compared, the best of them retained for further tests over a few seasons, the rest being discarded. The results of this method are evident, as mentioned already, in most of the improved varieties now in vogue all over the world.

The chief trouble in this selection work is the difficulty of distinguishing between variations that are heritable and fluctuations which are not heritable. Selections from the latter will be of no avail as they will simply repeat the parental performance.

Luther Burbank.—Perhaps the most outstanding example of the ability to spot desirable variations was Luther Burbank, often known as the Plant Wizard. Born in 1849 in the State of Massachusetts, U. S. A., he was the thirteenth child in a family of fifteen. His education was completed when he was nineteen, but his knowledge of plants was acquired mostly outside school hours. A library copy of Darwin's " Variation of Plants and Animals under domestication " furnished the initial stimulus, and under the encouragement of his elder cousin, Professor Levi Burbank, his enthusiasm soon got directed into fruitful channels. In 1870 he bought a 17-acre plot of land near Nunenberg, Massachusetts, and set up as a nurseryman and market gardener. Two years later he achieved his first success, in his " Burbank " potato. Prior to this, even the best variety, the " Early Rose, " had only small tubers with pink-coloured flesh when cooked. Burbank was lucky enough to spot out one of those rare " seed balls " or fruits on an " Early Rose " potato plant. He very carefully collected and sowed the seeds from this fruit. Among the 23 seedlings that grew up, two were decidedly superior to the parent type both in yield and quality, with large, smooth white-fleshed tubers. Burbank kept the better one of these two plants and discarded all the rest. He then sold this lucky find of his to another nurseryman for 150 dollars to be multiplied for distribution under the name of " Burbank" potato. With this money he migrated to California, where three of his brothers had already gone and settled at Santa Rosa, arriving there with just a few books, ten dollars, and ten of those Burbank potatoes that the nurseryman had allowed him to retain. Here he set up a nursery garden with a green-house attached and soon developed it into a world-famous centre of plant breeding—or as he liked to call it—" a factory of new plant-creations. " In the course of his next fifty years of work here, there was hardly a single important plant that he did not handle. Various forms of apples, cherries, peaches and nectarines were bred out and distributed. Among flowers, he specialised in lilies, utilizing over fifty different types in producing a brilliant array of new forms. Besides the Burbank potato, his first contribution to agriculture, he also produced numerous other varieties—in tomatoes, maize, garden peas and wheat. After nearly sixteen years of endeavour, he succeeded in evolving a spineless cactus. On berries, where he put out about 10 successful commercial varieties, he had to work for well over 35 years, involving the study of over fifty different species of *Rubus.*

Throughout his long and famous career, however, Burbank was never a scientist in the usual sense of the term. He was neither

a theorist nor an investigator, but only a practical biologist. In this respect, he was the opposite of men like Darwin and Mendel. " I shall be quite content " he used to say, " if because of me, there shall be fairer flowers and better fruits in the land." Though often acclaimed as a plant wizard, able to create new forms almost at will, his methods were all simple and straight-forward. Selection, rigorous to the point of being even ruthless, right from the earliest seedling stage, was the bedrock of his success. His usual method was to grow a very large number of plants in each sort, explore the range of variation among them and then to select only those that struck him as exceeding this range and showing promise of developing into a desirable type. His own belief in this sort of " second sight " gathered strength in later years, when he found that even accredited scientists were unable to copy or sometimes even to appreciate his methods. Minute differences of leaves, spines or branching habit, were all significant and aided him to thin out his beds and nursery rows without waiting till their fruiting stages. Many of his views were of course not strictly scientific, as for example his firm belief in the heritability of acquired characters, and he was content merely to use his talents without formulating or even explaining them to others. However, his intense devotion to his work, and supreme confidence in his own abilities made him one of the most remarkable plant breeders of all time.

Gregor Johann Mendel (1822-1884).—In marked contrast to Burbank's· methods were those of Mendel. Mendel was born in Austria in 1822. In 1851 he went up to the University of Vienna and studied Physics, Mathematics and the Natural Sciences for two years there. After his return to his native place of Brunn (now known as Bruno in the late Czecho-Slovakian State) he became eventually the Abbot of the House of St. Thomas, a body of Augustinian monks. Here, in his private garden, he commenced his experiments on the hybridization of garden peas. The results of 10 years of work on this plant were published in 1866 as a brief paper in the Naturalist Society of Brunn, but for the next thirty-six years this work remained unknown to the world of science. It was only in 1900, sixteen years after Mendel was dead, that this paper was re-discovered independently by three scientists, Hugo De Vries, Correns and Tschermak. Mendel's work is perhaps all the more interesting to us on this account, that he angled for no fame. His devotion to scientific knowledge stands as a silent rebuke to that feverish craze for publicity which is the bane of present day scientific activities.

Mendel's great achievement was in completely tracking down a single pair of contrasting characters, instead of getting lost, as so many of his predecessors did, in trying to study the hybrid as a whole. Taking the garden pea, he crossed a tall plant with a dwarf one, saved up the seeds and sowed them. All of them grew up into tall plants, tallness being thus " dominant " over dwarfness. The seeds from these tall hybrids when collected individually and sown again, gave in the next generation both the dominant talls as well as the " recessive " dwarf plants. Mendel counted them and found they were in the ratio of 3 talls to 1 dwarf. Proceeding further he collected the seeds from these two sorts, and sowed them again. One-third of the tall plants bred true for tallness, while two-thirds threw out—or in other words " segregated " into talls and dwarfs, again in the ratio of 3 : 1. The dwarf plants always bred true for dwarfness. The principle of independent inheritance of unit characters, and the fact that they could be grouped into fresh combinations by crossing and subsequent segregation, laid the foundations of modern genetics. Later work has shown that often two or even more characters may be controlled by the same genetic factor, and likewise two or more factors may also find expression in the manifestation of the same character. Such agriculturally important characters as yield, earliness, and quality and disease resistance are very complex in inheritance, being governed presumably by numerous " unit characters," and their modifiers.

Chromosomes—the physical basis of heredity.—All living bodies are made up of minute elements called cells. These are very numerous and very small, being only 0·1 to 0·001 mm. in diameter and differ enormously in shape, structure and function, but are nevertheless very much alike in certain fundamental characteristics. A typical plant cell consists of a mass of a clear jelly-like substance called " protoplasm " (which is believed to be the basis of all living matter), surrounded by a wall of cellulose. In the midst of this mass of protoplasam lies a denser mass the " nucleus "—like a submerged lump of ice in water. The extra-nuclear protoplasam goes by the name of "cytoplasm". There is also usually in plants, a large central " vacuole " or sap cavity. This nucleus seems to be the directive centre of most of the activities of the cell. It is now known to be the repository of the genes or carriers of inheritance and is hence of supreme importance in the transmission of characters from parent to offspring.

Growth in all living bodies is the result of repeated cell divisions. The process of cell division involves radical changes in the appearance and structure of the nucleus. When the cell is in a state of rest, the nucleus is seen to possess a distinct nuclear membrane, with a clear nuclear sap inside, in which is suspended a network (or reticulum) of a dense, readily-stained substance termed " chromatin ". This chromatin network, or rather, the minute structures included in it, is now looked upon as the seat of the hereditary factors. When the cell is about to divide, the nuclear membrane breaks down and the chromatin reticulum resolves itself into a definite thread, which subsequently breaks up into separate pieces, the *Chromosomes*. The number as well as the individuality of shape of such chromosomes is constant in all the body cells of any one species. In view of their importance in the transmission of characters these chromosomes have been subjected to the closest scrutiny. This study of cells and their components is now a separate science by itself, called *Cytology*. The net result of this intensive study is that the chromosomes, or rather some of their component parts, the " chromonema," are the carriers of the hereditary units, or " genes. " The ultimate composition of these " genes' is still obscure but we know that in them are to be found the sources of heredity and sex, mutations and evolution.

Mutations and Evolution.—Although the chromosomes are ordinarily remarkably constant in number, shape and structure, cases sometimes occur, where the number gets either halved or duplicated, or altered in other ways. Changes also occur in the number or arrangement of gene location within the chromosomes. The causes influencing these aberrations are still obscure, but the position may be likened to a bird chased off a telegraph wire by a small boy's stone, wedging itself into another roosting place without dislodging any of the crowded birds already there. The effect, however, of such aberrations is that new plant or animal forms are produced. These are termed *mutations* or sports in popular language. They often prove true-breeding and valuable from an economic point of view. In Nature, if these structural changes of chromosomes prove favourable for survival, they survive; if not, they soon get eliminated. It has been possible after extensive studies of the chromosome behaviour as well as the inheritance of characters, to trace the genes controlling the manifestations of specific characters, to definite locations on the chromosomes themselves. In maize, for example, 150 genes have been now worked out after many years of laborious

work, and mapped out on its 10 chromosomes. In *Drosophila mela-nogaster*, the American fruit fly, where there are 4 pairs of chromosomes, 110 such genes have been mapped out.

Although the principles of plant breeding are the same for all crops, in practice, a few points of difference exist between different crops in different regions of the world. Thus, the crops in the temperate countries of Europe were the subject of empirical study and selection, for nearly two centuries before Mendel's discoveries laid bare the principles of genetics. Tropical crops, especially in regions like Africa, Malaya, Java and the Philippines, have not had this intensive study. In India and China with their hoary civilizations, the position is slightly different. Here agriculture dates from even pre-historic times, but the lines on which it had been developed, though effective enough in those olden days, now require to be modernized under the stress of increasing populations and land values. Often the holdings here are very small, age-old traditions militate against the adoption of new methods, the margin of profits is very low, and owing to the fact that empirical selection has taken place in almost all the staple crops, further improvements are difficult to achieve.

The efforts of the plant breeder are closely linked with those of the agronomist. As an instance, the thin U. P. canes yielding normally 10-12 tons per acre, gave under improved cultivation, up to 35 tons of cane, but failed to ripen satisfactorily and so gave only a poor yield of sucrose. The benefits of improved cultivation such as manuring, trenching, better regulated irrigations, etc., could be realized only with the improved canes from Coimbatore. Likewise, the new types, evolved by Dr. Barber and T. S. Venkataraman, could not have proved their worth, in the absence of efficient cultural methods.

The chief achievements in the domain of plant breeding in its modern aspects are given below : —

Rice (Oryza sativa, L.).—As one of the oldest of cultivated crops, primitive methods of selection have been at work on rice, from time immemorial, so that the varieties now run up to some thousands. The annual production of husked rice in Madras is estimated at about 5 million tons. This quantity is, however, much less than that needed by the population of the province, and necessitates heavy imports. The urgent need to make the Presidency self-sufficient in rice production is sought to be met by breeding high-yielding strains.

In Madras 63 improved strains have so far been evolved and distributed. Of these, the most famous is of course G.E.B. 24, although all the strains yield from 10-25% more than the local types. It is estimated that about 1½ million acres out of a total of 10½ millions are now under these improved strains.

Attempts are also being made to produce new varieties by duplicating the chromosome sets by colchicine treatment and X-rays. A number of mutations were induced in G.E.B. 24 by X-rays and among them has been found a dwarf, late type yielding about 10% more than G.E.B. 24 itself.

Sorghum (*Sorghum vulgare*).—Among the millets, the food crops of the poor, sorghum is the most important. In India it occupies nearly 35 million acres out of a total of 61 million acres under millets. In Madras, the area of sorghum is a little over 4½ million acres out of 13 millions under millets as a whole. The chief features about this crop are that it can grow on much lower moisture levels than any other crop. The grain serves as a very sustaining food for men, and the abundant straw provides a nutritious fodder for cattle. Relatively to grain, sorghum gives a higher out-turn of fodder than any other important cereal and is therefore very valuable in animal husbandry.

Four good strains—A. S. 29, A. S. 1093, A. S. 1575 and A. S. 2095 have been evolved at Coimbatore, for the districts of Salem, Coimbatore and Trichinopoly. For the northern tracts, out-stations exist, and here T-1 and T-12, and T-6 and N 29|68 have proved their worth in the Ceded districts, J-75 in Guntur, and No. 14 in the Tinnevelly area. In Ragi—the strain E. C. 593 has been an outstanding success almost all over the Presidency.

Cotton.—This crop is one of the most important in international trade. Even in our own province, where the total area under cotton is only about 10% of the total area in India, it takes the first place with regard to its value in the export and import trade. A special feature of Madras Cotton is that over 90% belong to medium staple varieties. Among the Karungannies in the Tinnevelly tract, K-1 is a recent notable achievement. In the Northerns and Westerns of the Ceded districts, there is the strain H-1 at Hagari, and N-14 in the Nandyal tract. At Coimbatore also a number of good strains have been evolved in the irrigated Cambodia Cotton, Co. 1 and Co. 2 being two notable instances.

Groundnuts.—A. H. 25 and A. H. 32 are two superior strains in favour with the cultivators of this Province.

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Sugarcane.—Madras is well suited climatically for sugarcane cultivation. It was recognised early enough that quicker improvement was possible by introducing exotics or using exotic parents for crossing with the existing local varieties, Nanal, Poovan and Vellai. Thus there came into being a number of imported strains from Mauritius, Fiji and Java. Some of them, *e.g.,* 247-B; Fiji B ; P. O. J. 2878 are still popular.

About 1930, strains specially intended for Madras conditions were evolved and introduced. The most popular of these Coimbatore selections are the Co. numbers—213, 281, 360, 402, 408, 413, 417, 419 and 421. The phenomenal success of these nine strains is indeed a notable achievement ; these having replaced the local types on over 50,000 acres, with an estimated extra gain of over 15 lakhs of rupees to the cultivator.

Maize (*Zea mays*) or corn as it is known in America is one of the most important cereal crops in the Western Hemisphere. The genetic study of maize has been very intensive. About 150 genes have been located on its 10 pairs of chromosomes. On the practical side of breeding, its cross-fertilized nature has led to some modifications of the usual breeding methods. Although maize was one of the earliest crops where breeding experiments were conducted, yet fewer improved strains have been put out here than with wheat and oats. The reason is, that the older methods of selection resulted in considerable in-breeding, with consequent loss of vigour, size and yield. Maize is peculiar in that male and female flowers are borne on different parts of the plants, and so in Nature, seed-setting depends primarily on wind-pollination. The pollen is carried about by wind from the male inflorescences and gets wafted on to the stigmas or receptive organs on the female inflorescences, of other plants in the field. In this kind of out-pollination where sexual elements from two different plants unite, the progeny is larger and more vigorous than when the pollen is used on the stigmas of the same plant. This is known as hybrid vigour. The mule is a classic instance of hybrid vigour, where the product of mating a mare with an ass, has produced an animal much hardier than the horse and much larger and stronger than the ass. The exact nature of hybrid vigour is still not fully clear, but in maize it has been turned to advantage in producing what the Americans term as "hybrid corn". The details of the process is as follows. By selfing for a number of generations, a number of pure lines are secured, that are free from defect-carrying genes such as those for dwarfness, sterility, chlorophyll deficiency, etc. By a judicious inter-crossing of such purified

selfed types, factors imparting vigour are recombined to give hybrids very much more vigour than the original parents themselves. The maximum vigour exists of course only in the F-1 or the first generation. Hence, in utilizing hybrid maize in America, steps have been taken to have a sufficient number of centres to multiply the hybrid seed, as well as to maintain a stock of suitably purified and combinable selfed pure lines.

In certain fruits and vegetable crops, such as tomatoes and brinjals, the seeds produced in even a single fruit are so numerous that it is possible to put hybrid seed on the market, to produce very large and heavy yielding hybrid plants.

Breeding for disease resistance.—We have dealt so far with the productive aspect of plant breeding. There is, however, another side, the protective aspect, whereby losses from pests and diseases are sought to be avoided by breeding strains that are able to withstand insect attack and various fungus and virus diseases. Thus in wheat and other grain crops, the rusts are perhaps the most important of all fungus diseases, entailing the loss of millions of pounds annually. The task of breeding rust-resistant strains, however, is not made easier by the fact that over 50 distinct races of rust are recognised in wheat alone, each with its own peculiar relations to different wheat varieties. However, the recent work of Hayes, Stakman and others in America, and Mehta in India indicate that wheat varieties resistant to a number of local races of rust can be evolved, with a reasonable degree of success. Thus Biffen's " Little Joss " is resistant to yellow rust (*Puccinium glumarum*) in England and McFadden's "Hope" has been found in America, resistant or nearly so, to all the known physiological forms of black rust.

Potato.—The blight disease and the wart disease (caused by *Phytophthora infestans* and *Synchytrium endobioticum*, respectively) are two of the most serious obstacles to success in potato growing. The breeding of resistant varieties seems to offer the only hopeful line of attack. After Vavilov's discovery of numerous immune wild forms in Peru with also other desirable characters, the prospect of synthesising a good quality, high-yielding and immune variety seems promising.

With regard to the wart disease, Salaman in England showed that resistance behaved as a simple dominant to susceptibility. A series of types have accordingly been evolved, namely Arran Victory, Arran Crest, Arran Pilot, Arran Banner, etc. that are resistant to this disease.

In connection with the breeding of disease resistant types in crops, the story of U_4 cotton in S.-E. Africa may be interesting. Early attempts at cotton cultivation in S.-E. Africa were all failures, owing to the attack of a small insect, known as Jassid, a kind of leaf-hopper that sucks away the plant sap, leaving the plant weak and stunted. Parnell, after five years of work at Barberton (in Transvaal), succeeded in evolving a strain from a single green, healthy plant in a severely jassid-infested field. This strain he called U_4. It was so resistant to jassid attack that within a short period, it spread all over South and East Africa. Further work has since then been directed towards eliminating the existing drawbacks such as a small boll, harsh lint, etc., in U_4 and making it still better.

In Rice, as mentioned previously, a strain resistant to paddy blast was discovered in G. E. B. 24 at Coimbatore and subsequently improved further by hybridizing it with Korangu Samba.

These examples, although by no means exhaustive, serve to show the value of plant breeding methods in combating pests and diseases.

The prospect for the future.—The facts pertaining to the growth of the world's population in relation to the rate of increase in available food supply, leave no reason for doubt as to the future status of plant breeding. As the problems of human welfare become more acute, the demands on agriculture will stimulate a corresponding increase in the efforts to apply scientific knowledge in the production of the world's supply of food, textiles, rubber and wood. Plant breeding will certainly play an essential role in the necessary increase of these vital commodities. How important or how successful this role is, would depend upon the advancement in genetic research.

INDIA AND CHINA

By

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Happening to read recently Chavannes' article Les Inscriptions Chinoises de Bodh-Gaya *(Revue de l'Histore des Religions, Vol. 34, 1896 pp. 1—58) I felt that some parts of it were of wide general interest and should be known better than they have been. Hence some brief notes from the article and a translation of some pages of general interest are published below. The translated passages are put under quotation. The rest is an abridgment omitting details which are of no great interest to the general reader.*

The five inscriptions of Bodh-Gaya of the tenth and eleventh centuries A. D. (one mid. 10th century, three dated 1022, last 1033) must be a small part of the antiquities left by Chinese Pilgrims.

The most ancient record is that of Wang Hiuen-tse, ambassador to Harṣa Śīlāditya in 646. He came only in 655 when Harṣa was about to die; repulsed by the usurper Arjuna, he retired to Tibet. The king of Tibet, Strong-san-sganpo died in 650; his two queens, a Chinese princess and a daughter of Aṁśuvarman, maintained a close connection between Tibet on the one hand and China and Nepal on the other. The Chinese envoy gathered a force of 12,000 Tibetans and 7000 Nepalese, overcame the princelets of the Ganges valley and returned with booty in 661. He offered to the emperor his captives including Arjuna and this was commemorated by inscribed statues. An earlier mission of Wang Hiuen-tse in 643 is attested by another source which records an inscription in Gṛdhra-kūṭa made at the time of this mission to Vimalakīrti who lived N.E. of Vaiśālī.

I-tsing (673-85) saw an inscription in the temple of Mahābodhi *(Religieux Eminents* p. 30). Three centuries later monk Fa-yu coming to India a second time c 932 wished to make an inscription in the name of China near the diamond throne of Buddha.

Hoai-wen (1031) engraved extensive texts at the foot of the stūpa he built at Bodh-Gaya.

From these data and from the inscriptions themselves now discovered, we see that most of the Chinese *steles* of India group themselves around the temple of Mahābodhi, the diamond throne. Yuan Chwang maintained relations with it even after his return to China. Many of I-tsing's numerous contemporaries had gathered there, and some of them made a home there. Three Chinese Vihārasvāmis, one of them a nephew of envoy Wang Hiuen-tse, are known. I-tsing himself regarded his visit to the diamond throne as the supreme aim of his pilgrimage.

Song texts are fewer and more succinct than *T'ang* on the Chinese in India and we are thrown on general cyclopaedias treating of the age.

In 964, when the Song had hardly been five years in power, 300 pilgrims started for the holy lands (India); they travelled for twelve years; one of them Ki-ye has left a short account of the journeys. In 965 Tao-Yuen came back to China after an absence of 18 years. In 966 A.D. 157 persons responded to an appeal of the Emperor who wished to send a mission to India. In 978 Ki-tsong and his companions returned to China; in 982, Koang Yuen; in 983 Fa-yu who again went out almost at once; between 984 and 987, Tse-hoan; in 989 (990?) Tch'ong-ta who had stayed away from his country for ten years. Finally in 1031 Hoai-wen went to India a third time, returning in 1039 after engraving in 1033 the record now preserved in the residence of the Mahant at Bodh-Gaya.

There must have been many of whom we have no record, e.g., none of the authors of the 1022 inscriptions is mentioned in the annals. We know further there were in the court of China in 982 many Chinese śramaṇas who knew Sanskrit, and they too most probably were pilgrims to India.

One remarkable thing. A number of these did not travel without being charged with quasi-official missions by the Emperor. The 157 pilgrims of 966 carried letters to all princes of Central Asia and North India; Fa-yu took letters to Sumatra, etc., in 983. In India they did many things for their Emperor. Koang-yuen, who returned to China in 982, could show by the letter of a Hindu prince that he had offered to the Buddha of the Diamond throne a *kaṣāya* on behalf of the Emperor; Hoai-wen acting on the express orders of Jen-tsong and the Dowager Empress built in 1033 a pagoda at Bodh-Gaya; the Hindu monk Kio-kie, who came to China in 1010 received by Imperial decree a *kaṣāya* woven with gold for presentation to the· Diamond throne. In the T'ang period the pilgrims do not seem to

have been so charged with duties by the emperors on their account; the first Song emperors alone used them as messengers of their personal devotion.

"If Chinese Buddhists came to the holy places consecrated by the veneration of the faithful, the Hindus in their turn betook themselves to a court where they were assured of an eager welcome. We have perhaps too long mistaken the role played by the Hindus in the propagation of their faith. The interest excited by the Chinese pilgrims has thrown in the shade the work accomplished by their coreligionists of India. In reality the translation into Chinese of the texts of the Tripitaka is equally the work of both the classes. It is not only in the epoch of the T'ang that we can find these strangers coming in; in the 10th and 11th centuries Buddhism is still so prosperous in its home country as to send out missionaries to preach the good law in other lands; it was perhaps the last flash of a dying fire; but still the divine flame was making its vivifying influence felt as far as northern China. In 972 there came to T-Ch'angngan the Śramaṇas K'o-tche, Fa-Kien, Tchen-li, Son-ko-t'o and fourteen other monks from Western India; in 973, the Emperor received with great honour a śramaṇa from the temple of Nālandā, Fa-t'ien, who took in 982 the name Fa-hien, and lived in China till his death which occurred in 1001. In 971, Mañjuśrī, the son of the king of Western India, and in 977, Ki-siang, śramaṇa from Western India, came to live in the capital of China for a considerable period. In 980 we note the coming in of T'ien-si-tsai, native of Kashmir, of the Che-hou from Udyana, and Hou-lo from Central India ; the Emperor T'ai-tsong then conceived the project of making new translations of sacred texts and of continuing the work that had been interrupted for nearly two centuries; he established in 982 " a Court of Translation" with three Hindus, Fa-t'ien, T'ien-si-tsai and Che-how, at its head ; it is perhaps to their activity that we owe the best part of 201 works which enriched the Chinese Tripitaka during the twenty-nine years that followed (982-1011). The Sanskrit texts on which they worked appear to have been numerous; if we may trust the *Fo tsou t'ong ki*, nearly all the pilgrims that came or returned to China brought with them some Sanskrit sūtra on palm leaves; it is then possible that we may discover some day in the convents of *Chen-si* the originals of which we now have only the Chinese versions. The institution of the " Court of Translation " and the redoubling of the interest manifested by the Emperor for Sanskrit studies could not but attract numerous Hindus to China; they began to arrive in crowds; thus, between 984 and 987, Yong-che ; in 989, Pou-t'o-k'io-to, śramaṇa of the temple of Nālandā ; in 995, Kia-lo-chen-ti from Central India ;

in 999, Ni-wei-ni from Central India and Fo-hou from Western India; in 1004, Fa-hou from Western India and Kie-hien from Northern India ; in 1005, Mou-lo-che-ki from Kashmir and Ta-mo-po from Western India; in 1010, Tchong-t'e from Western India and Kio-kie from Central India; in 1011, Tsi-hien from the kingdom of Pan-ni ; in 1013, Tche-hien from Western India; in 1016, T'en-kio from Udyana, Miao-te' from Ceylon, T'ong-cheou from Central India, P'ou-tsi from the kingdom of Varendra in Eastern India and so many others with them that the author of the *Fo tsou t'ong ki* declares that no time were there so many Hindu monks in the Court. Then there are, in 1024, Nagai-hien-tche, Sin-hou and their companions from Western India ; in 1027, five monks, Fa-ki-Siang among them; in 1036, Chan-tch'eng and eight other śramaṇas.

" This era of prosperity, however, came to a sudden end. The history of the Song closes its notice of India with the year 1036, though the dynasty lasted for nearly two centuries and a half more; if the chronicler stops there, it is doubtless because he has nothing more to say, and after 1036 the relations between India and China came to an end. A study of *Fo tsou t'ong ki* suggests a similar conclusion; this Encyclopaedia mentions the arrival in 1053, of Tche-ki-siang, a śramaṇa from Western India; but after this date, it does not mention any Chinese pilgrim or Hindu missionary. Lastly, a third consideration reveals to us the great blow sustained by Buddhism in China in the middle of the eleventh century: in 1021, there were in the Empire 375,615 monks and 61,240 nuns ; in 1034, there were still 385,520 monks and the nuns numbered 48,470; but in 1068, there were only 220,660 monks and 34,030 nuns.

" The causes of this sudden turn of fortune are not very apparent. Buddhism was not persecuted in China in the eleventh century; we find in this period none of the edicts of proscription which at the other times checked its growth. But the influences which undermined Buddhism then were not the less powerful for their being secret and hidden. If Buddhism succumbed, it was not before enemies who employed temporal arms; it was in a battle of ideas that it was worsted. In short, in the second half of the eleventh century there developed the grand offensive of the learned rationalist movement which must have been an intransigent reaction against all the principles received from outside; Han K'i (1008-1075), the illustrious historian Se-ma Koang (1009-1086), Tcheng Hao (1032-1085) and his brother Tch'eng I (1033-1107), then, in the twelfth century, the celebrated commentator and philosopher Tchou (1130-1200), in a word all the lights of this strong school which formed

more or less the scholastic of Confucianism, fought the Buddhist beliefs hard and without mercy.   When we see how the spirit of the cultivated classes in China is, even to-day, imbued with doctrines professed by the *literati* of the Song epoch, we can understand what immense authority they must have commanded in their life-time, and can no longer be surprised that Buddhism was unable to resist such strong assailants.

" About the same time, Buddhism passed in India through a graver crisis which turned out to be fatal.   The Muslim invasion was not perhaps its immediate cause; the conquests of Muhammad of Ghazni (1001-1030) coincide on the contrary with the period when the religious communications between India and China were most close and frequent. Islam must have had, however, in an indirect manner, some influence on the destinies of Buddhism.   By hindering the rise of powerful indigenous dynasties in northern and central India, it did away with the accredited protectors of Buddhism who during many centuries had sustained it by their princely donations and encouraged it by their edicts of good will; doubtless we still find in the twelfth century an Asokaballa,* king of Sapādalakṣa and a Vidyādhara, † son of a minister of Gopāla, king of Gādhipura, who still profess the Buddhist faith, but these are unimportant exceptions; in fact the Pālas who disappear at the commencement of the eleventh century were the last great Buddhist sovereigns who reigned in the basin of the lower Ganges.   More and more Buddhism was left to itself.   For a young and ardent religion, separation from the secular power might become the signal of an era of renewal and reconstruction; for a cult already old and no longer a venerated institution of the State, it is ruin.   Such was the case with Buddhism.   Deprived of the support of kings and lacking internal vitality, Buddhism enters towards the middle of the eleventh century into that long and lamentable decadence during which it gradually effaces itself in order that the antique social organisation of the Brahmans may come up again.

" In seeking to trace the historical conditions in which the inscriptions of Bodh-gaya had their origin, we have been led to point out the existence, at the end of the tenth century and the beginning

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* The Three inscriptions of Asokaballa are dated in the years 1157, 1175 and 1180 A.D. Cf. Cunningham, *Mahābodhi*, pp. 78-81.

† Kielhorn has shown that the inscription of Vidyādhara is dated Sam. 1176, not 1276, and thus before the Muslim conquest of Kanouj (Gādhipura). IA. xxiv p. 176 (correcting xvii, p. 61).

3

of the eleventh, of a period of revival in the religious intercourse between India and China. We know very well the great movement of Buddhist propaganda the full efflorescence of which occurred in the seventh century with Hiuen-tsang and I-tsing; but hardly any attention has been given till now to the awakening of faith three centuries later. For one who takes a broad view of them, the voyages of Buddhist pilgrims hold an important place in the intellectual history of humanity; the obscure śramaṇas whose names alone have floated down to us, and those even more numerous who must remain forgotten for ever, accomplished a high and noble work, for they brought together whatever was best and most universal in two civilizations. Carried away by one of those irresistible currents which, at certain epochs, move and agitate peoples unconsciously, they crossed large rivers and snowy mountains, traversed deserts and seas, and overthrowing the barriers raised by the hatred of races, they united the peoples in an intimate communion of thought and soul. It is interesting to follow to its last phase this pacific impact of two worlds.

" Before being eclipsed by the doctrines of the Chinese literati, before declining gradually in India, Buddhism had thus once more inspired with the same pious zeal the two most numerous agglomerations of men on the face of the earth. In spite of the latent germs, which were already working towards its dissolution, it caused a blossoming of the flower of sacred enthusiasm from the sides of the Hoang-ho to the banks of the Ganges. Although declining, it seemed to recover life ; it is in a supreme outbreak of splendour that the twilight of its gods begins. The steles of Bodh-Gaya are the vestiges of this final glory; erected to celebrate the power and majesty of Buddhism, they have become the tomb-stones under which lies buried the religion that was held to be eternal."

names refer to the same person. There are a few other records similar to this (500 of 02, 94 of 1934-5, 520 of 02, etc.).

A record from Tiruvennainallūr (496 of 1921) of the 6th year of Kōpperuñjiṅga (acc. 1243 A.D.) records a series of gifts of later date—two at least of the 9th year—(idan mēl Aḻagiya Śīyan Kōpperuñjiṅga dēvar nāḷil—l. 10) : and these two names refer only to one person.

The Vailur and the Tiruvēndipuram records should refer to this chief. Mr. V. V. Aiyar admits that both these records "appear to be complementary to each other" and that "the battle of Teḷḷāru was probably fought prior to the Śendamangalam incident," but has erred in *not* assigning them to this chief. Thereby he has deviated from the sound position taken up by Hultzsch (E. I. VII No. 23).

The Villiyanūr record, according to the existing text, is dated in the 6th year of Sakalabhuvana Cakravartigaḷ Śrī Avani Āḻappirandān Kōpperuñjiṅga dēvar (l. 1). A royal officer instituted an inquiry into the accounts of the temple for the period from the 37th year of Tribhuvana Vīra dēvar (Kulōttunga III) to the 11th (year?) of Aḻagiya Śīyan Kōpperuñjiṅga dēvar in the month of Thai of the 6th (year). And after the inquiry it was resolved that from the 21st day of Thai of the 6th (regnal year) two perpetual lamps were to be burnt everyday by the Śiva Brahmanas.

The record as such is difficult to interpret from any standpoint. It is capable of three interpretations.

First. As contended by Mr. V. V. Aiyar, there should have existed two Kōpperuñjiṅgas : the first with accession in 1232 A.D. and the second in 1243 A.D. According to this theory, the same chief (called Kōpperuñjiṅga I acc. 1232 A.D.) who designates himself as Sakalabhuvana Cakravarti Śrī Kōpperuñjiṅga *alias* Aḻagiya Śīyan, the Conqueror of Śōṇāḍu (Vailur), becomes identical with Maṇavāḷapperumāḷ in his 5th year (Śendamangalam), and in the same year (1237 A.D.) is equated with Aḻagiya Śīyan Avani Āḻappirandān Kāḍavan Kōpperuñjiṅga *alias* Sakalabhuvana Cakravarti Avani Āḻappirandān Kōpperuñjiṅga (Chidambaram 463 of 02 and Āttūr 285 of 21); and again, in the 11th year (i.e. 1243 A.D.) he is said to be referred to as Aḻagiya Śīyan Kōpperuñjiṅga in a record of the 6th year of another chief called " Kōpperuñjiṅga II " (Villiyanūr 186 of 1936-7). How are these to be reconciled ?

.   The order of succession of the rulers of this region is given in a record at Kāṭṭumannārkōil (570 of 1920) and the only Pallava ruler mentioned, namely *Avani Āḻappirandān Kōpperuñjiṅga dēva*

is placed between the Cōḻa Rājarāja (III) and the Pāṇḍya 'Perumāḷ Sundara Pāṇḍyadēva'. If there were two such Pallava rulers, they would have been mentioned in this record.

Further is it conceivable that a chief began his royal career under the shadow of a great disaster (1232 A.D.) inflicted by the Hoysalas as recorded in the Tiruvēndipuram record ?

Lastly granting for argument's sake, that the Aḻagiya Śīyan Kōpperuñjiṅga (l. 4) of the 11th (year) mentioned in the body of the record of Sakalabhuvana Cakravartigal Śrī Avani Āḷappīrandān Kōpperuñjiṅga dēva (l. 1) refers to 'Kōpperuñjiṅga I' we meet with certain difficulties. The inquiry into the accounts of the temple of Villiyanūr Udaiyār Tiru Kāmīśvaramuḍaiya Nāyanār began in the 6th year of Kōpperuñjiṅga (Kōpperuñjiṅga II of Mr. V. V. Aiyar, accession 1243 A.D.). The accounts of the temple for the period spreading from the 37th year of Tribhuvana Vīra dēva, i.e., Kulōttunga III to the 11th year of Aḻaga śīyan Kōpperuñjiṅga (Kopperuñjiṅga I of accession 1232 A.D. according to Mr. V. V. Aiyar) i.e., from 1215 A.D. to 1243 A.D.

The record is then silent for the intervening period from 1243 to 1249 A.D. (the first six years of Kōpperuñjiṅga II ?). The unsatisfactory state of the temple accounts was discovered in the 6th year, and after inquiry it was ordered that two perpetual lamps should be burnt from 21st day of Thai of the 6th regnal year (l. 8 of the record) of Kōpperuñjiṅga. Therefore the inquiry should have related to the whole period from 1215 to 1249 A.D. This is impossible to deduce if we postulate an Aḻagiya Śīyan Kōpperuñjiṅga I with accession in 1232 A.D.

Second. A second interpretation possible is that a record of the 6th year started an inquiry and that it lasted till the 11th year of the same chief. Such a series of transactions is recorded in a Tiruveṇṇainallūr record mentioned already (496 of 1921). We cannot accept such an interpretation here because it is laid down that as a result of the inquiry two perpetual lamps were ordered to be burnt *from the 21st day of Thai of his 6th regnal year* (āravadu tai mādam irupattonrā (n) tiyadi mudal—l. 8). Therefore the inquiry should have been completed by that time and it cannot be attributed to the 11th year.

Third. My explanation of this document is this : Aḻagiya Śīyan Kōpperuñjiṅga (of l. 4) is only the same chief as Sakalabhuvana Cakravartigal, Śrī Avani Āḷappirandān Kōpperuñjiṅga of the Introduction; but there is a mistake of the engraver in displacing the

order of a few words. In l. 4 after "Kōpperuñjiṅga devarkku" and before "padinonrāvaduvarai" should be engraved the words "aravadu tai mādattu" of line 5 i.e., the inquiry related to the period from 37th year of Kulōttuṅga (1215 A.D.) to 11th day of Tai of the 6th year of the King (1249 A.D.). In this way alone can we satisfactorily explain this record. The inquiry was started in the 6th year of Kōpperuñjiṅga; it related to the period, from 1215 to 1249 A.D. (37th of Kulōttunga III to 11th day of Thai of the 6th year of Kōpperuñjiṅga of acc. 1243 A.D.) after an enquiry lasting for 10 days the decision was taken on the 21st day of Thai of the 6th year. Such a mistake appears very plausible. Therefore it seems to me that the new dual theory of Mr. V. V. Aiyar also fails.

In conclusion, I hold that Pallavāndār, the Conqueror of Toṇḍaimaṇḍalam, is different from Kōpperuñjiṅga of the Vailūr and Tiruvēndipuram records, the conqueror of Śōṇāḍu, and it is wrong to call him Kōpperuñjiṅga I. The connection of Maṇavāḷapperumāḷ with Kōpperuñjiṅga is not yet established. There was only one Kōpperuñjiṅga and he had his accession in 1243 A.D. The Vailūr, Tiruvēndipuram records as well as all records with regnal years should be attributed to him.

Identification of Kūḍal

Let me add a note on the identification of Kūḍal. M. Dubreuil drew my attention to the existence of the name of a temple of Kūḍal Āḷwar in an inscription at Tīrthamalai. This place seems to have been the abode of a number of chiefs called 'Karkaḍa Mahārāyas.' Kūḍal may then be identical with Tīrthamalai (658, 660, 669, 672 and 673 of 1905); and this fits in very well with the description of the Vṛddhāchalam record Arasanārāyaṇan Āḷappirandān (74 of 1918) wherein is stated that 'this chief started westwards from the gate of Gaṇḍarādittan in the latter part of the month of Āḍi in Śaka 1108, destroyed Kūḍal of Karkaḍamārāyan and the land of the Adigaimāns (the region of modern Salem District), raised the flag of victory and featured the Hanumān there."

I thank both Rao Bahadur C. R. Krishnamacharlu, Superintendent for Epigraphy, Southern Circle and Mr. V. Venkatasubba Aiyar, the Epigraphical Assistant, for their courtesy in permitting me to examine the texts of the newly discovered inscriptions of this chief.

APPENDIX I

Lines 4 and 5 as at present.

......." Tribhuvana vīra dēvarkku muppattēḷāvadu-mudal *Alagiya Śiyar Kōpperuñjiṅga dēvarkku padinonrāvadu varai* i-koyil nīkki nilai kāśum

7

nellum āḍum māḍum *ārāvadu tai mādattu* Uḍaiyar Perumangalam Uḍaiyār....
Kaṇakkuk-kēṭṭu.

As Amended

......"Tribhuvana vīra dēvarkku muppattēḷāvadumudal *Aḷagiya Śiyar Kōpperuñjiṅga dēvarkku ārāvadu tai mādattu padinonrāvadu varai* i-koyil nīkki nilai kāśum nellum āḍum māḍum Uḍaiya Perumangalam Uḍaiyār......
Kaṇakkuk-kēṭṭu.

APPENDIX II

GENEALOGICAL TABLE OF THE KĀḌAVAS
(ACCORDING TO MY SCHEME)

[Vṛddhācalam 74 of 1918
Tiruveṇṇainallūr 463 of 1921]
(1) Vaḷandānār *alias* Kāḍavarāyar
|
(2) Āṭkoḷiyār *alias* Kāḍavarāyar

(3) Ēliśaimogan
Kāḍavarāyan
who conquered the
four quarters

(4) Araśanarāyanan
Kachchiyarāyan
alias Kāḍavarāyan
|
(5) Āḷappirandān
Viraśekhara *alias*
Kāḍavarāyan who
*destroyed Kūḍal of
Karkaṭamārayan* and
the land of the
Adiyamān
Śaka 1108=1186 A.D.
|
(6) Aḷagiya Pallavan
Aḷagiya Śiyan
or
Jīya Mahīpati
[Tiripurāntakam
197 of 1905
Munnūr—63 of 1919]

[Atti ⟨ 296 of 1912
269 of 1914
Mōrijonai 178 of 1921
Tirukkaḷukkunram
187 of 1932-33]

(5) *Kūḍal
Ēliśaimōgan
Āḷappirandān*
|
(6) Pallavāṇḍār *alias*
Kāḍavarāyar (or Virar
Viran Kāḍavarāyar)
the conqueror of
Toṇḍaimaṇḍalam
|
(7) Sakalabhuvana
Cakravarti
Avani Āḷappirandār
Śrī Kōpperuñjiṅga
or
[Mahārājasiṁha]
acc. 1243 A.D.
the conqueror of
Śōṇāḍu
|
(8) Kāḍava Kumāran
[480 of 02—Tiruvaṇ-
ṇāmalai record]

N.B.—For Mr. V. V. Aiyar's Table see *E.I.*, xxiv, No. 6.

A BRIEF SUMMARY OF THE PHILOSOPHY OF SĪTĀRĀMĀÑJANĒYA—SAMVĀDAMU.

BY

S. RAMAMURTI, M.A.

1. INTRODUCTION

The main source of the Sītārāmāñjanēya-samvādamu is the Adhyātmarāmāyaṇa, a brief conversation between Śiva and Gaurī in the Brahmāṇḍa Purāṇa.

The history of Telugu Literature can be roughly divided into three stages: 1. 1000 A.D.—1500 A.D. covers the period when the Sanskrit books were mainly transliterated and translated into Telugu. 2. 1500—1800 A.D. covers the age of synthesis. In this period the Telugu poets took a keen interest in combining one system with another. 3. 1800 A.D. onwards. This is the period of an impetus to expound more or less independent views.

By a careful study of our manual, we get an insight into the essentials of yōga and Advaita. Our text may be legitimately considered an epitome, in Telugu, of the two systems since in a small compass, by means of symmetrical presentation, it condenses all the important doctrines of yōga and Advaita–nature of the practice of yōga, food restrictions, place and accessories, elaborate discussion on the nature of samādhi, praṇava, ārūḍha, ārurukṣu, nāda, bindu; kalā etc.; and again the nature of Brahman, māyā, the jīva, Īśvara, sākṣitva-manana, sūkṣma-sthūlasṛṣṭi-prakāra, mahāvākya, jīvēśvaraikya, jīvabrahmaikya, jīvanmukta and so on.

Our author, Paraśurāmapantula Lingamurthy Gurumūrti, who flourished during the later half of the 18th century, deals primarily with yōga in the first part, devotes much to the exposition of Advaita in the second part, and in the third part gives a blending of the two systems. We have however given up the existing order of the text and followed the order of ontology, cosmology, psychology and so on. All the advaitic portions of the text find parallels in the Brahma Sūtras, in the Gītā and in the Upaniṣads like Bṛhadāraṇyaka, Chāndōgya and Śvētāśvatara, and in the works of Śaṅkara, while the yōga portions have their roots in the system of Patañjali, the teachings of Lord Kṛṣṇa, and in the Upaniṣads, like Hamsopani-

ṣad, Nādabindūpaniṣad, Śvetāśvatara and so on. Again, it is of interest to note that ' the nature of the source of the world, the subtle body and the order of creation have their source in the system of Kapila.'

2. BRAHMAN AS ABSOLUTE EXISTENCE, INTELLIGENCE, BLISS IMPARTITE.

Every rational being arrives at the conclusion that the Universe is a passing show and that there must be something (cause) for the appearance of this non-eternal world. It alone is absolute Reality without a second. It is devoid of all differences. It is transcendental, all-pervading and the inmost being of everything. Existence and non-existence are manifestation and non-manifestation of the same nature. The world is in the state of manifestation and māyā in the state of non-manifestation. Reality does not belong to either.

Brahman is absolute Existence and absolute Intelligence, witnessing from time immemorial the origination and destruction of the things of the world. Brahman is absolute Bliss. To every man his self is the dearest. For the sake of the Self whose intrinsic nature is bliss, man has aversion towards pain. Brahman is absolutely pervading. It is impartite. Reality is devoid of paricchēda or differences of all kinds, viz., 1. those created by space, 2. those created by time and 3. those created by things. If any of the above differences be attributed to Brahman, then Brahman would become limited and imperfect. Hence Reality is akhaṇḍasaccidānanda.

3. WITNESS CONSCIOUSNESS.

The Self is witness consciousness. The Cārvākas, the Yōgacāras, the Jainas, the Mīmāṃsakas, the Nirīśvara Sāṅkhyas, the Vaiśeṣikas and the Naiyāyikas hold the opposite view thinking that Self is identical with one or other of the five sheaths. They do not realise the fact that the sheaths are ultimately sublated. The Self is not witnessed by anything. If another exist to witness it, the second thing would require another to witness it. This leads to infinite regress.

There is no difference between Intelligence and akṣarapuruṣa. The latter is only a reflection of the former. In the form of residual potencies, karmas reside in the internal organ. Through the instrumentality of the organs and the like, Brahman knows everything. The self-luminous is the spectator of all. The nature of

the witness Intelligence can be realised by the Yōgārūḍha who sublates all the things of the world. Duties are not the means to his end. He gives up regard for caste, creed and lineage. The view that the mind is non-existent or the view that he is the seer of the organs and the like is enough to put him on the line of meditation.

When he serves the teacher heart and soul, and treats all creatures with the sense of equality after knowing the significance of the mahāvākya, he is known as ārurukṣu. He attains the stage of sādhaka, when his external and internal organs get fed up with discharging their duties like the spent-up-couple and when, by the potentiality of samādhiniṣṭhā, he realises that he is the secondless seer of this world of bhrānti. He remains without name and form and with the essential nature of non-dual consciousness.

4. On the Nature of Maya.

Its origin can be traced back to the Vedas and the Upaniṣads. In the sense of power it is saṅkalpa śakti. Gradually it has come to mean mystery, deception, non-reality, ignorance and illusion. Our author uses it in the sense of unseen energy and appearance. Māyā is not a doctrine nor a theory nor a code of rules. It is what we are and what we experience in this world. Our author is not right in holding that it is synonymous with paralaya, pradhāna and so on. Though there is no difference ultimately between māyā and avidyā, still in the empirical level one is objective and the other is subjective.

If one were to give a realistic interpretation of māyā by identifying it with śakti, then, both Īsvara and Śakti would be real and the result is duality of Reality. Idealistic interpretation of māyā lands us in subjectivism and nihilism. From the standpoint of ethics, it is real as long as the world exists. There is no ultimate value about it. To a mystic it is pure negation in the state of Turīya. From the point of view of metaphysics it is neither real nor unreal. It is inexplicable. Neither the relation of identity nor the relation of difference holds good in the case of Brahman and māyā, since one is Intelligence and the other non-Intelligence.

Māyā is not śūnyavāda since it holds that Reality is through and through positive. It is not concrete Reality, remaining in between the world and Brahman. It is not ordinary illusion as it accepts nescience as the positive entity. Māyāvāda is not agnosticism in that it admits progressive development of knowledge. Māyā is something like a label that indicates the finite nature of our knowledge. Unless we transcend māyā we cannot account for it.

Other systems are not free from difficulties since they cannot account for evil in this world.

5. GOD AND THE FINITE SELF.

God is Reality enveloped by māyā. Īsvara, the material and the efficient cause of the world, is the Lord of māyā which is of the nature of pure sattva. For Him the aggregate ignorance of all the beings is the causal body and the aggregate deep sleep is the state. He is called Vairājasa, Vaisvānara and the Virātpuruṣa. The latter is of the form of the universe. Our author gives another kind of interpretation in the light of yōga saying that the earth is the mūlādhāra-cakra of Īsvara, fire is His svādhiṣṭhānakamala and so on. With the names of Avyākṛta, Hiraṇyagarbha and Virātpuruṣa and as conditioned by the aggregate causal, subtle and gross bodies, He is worshipped by the finite Self.

In avidyā which is of the nature of impure sattva, Brahman, its source, is reflected by the name of 'jīva'. Conditioned by the individual causal, subtle and gross bodies and possessing the principle of individuation, he goes by the names of Visva, Taijasa and Prājña. Individual ignorance is his causal body and individual deep sleep is his state.

Creation means nothing but bringing into light the form and the name of a thing. For the fulfilment of that wish, Brahman needs the co-operation of avidyā which causes and aids the fructification of the karma of the finite selves. This provoking leads to the following results: Ākāsa emerging out of Brahman, enveloped by impure nescience possesses sound as quality. From it all the other elements have come into existence. From the two halves of individual and aggregate sattvaguṇa belonging to the five elements, the external and the internal organs spring up with their presiding deities. Similarly, the two halves of individual and aggregate rajoguṇa give birth to the conative organs and vital airs. Each of the elements of impure sattva is divided into halves. Each half is divided into four parts. These parts are respectively mixed with each of the essential halves. This quintuplication gives rise to the gross worlds.

As there is plurality of adjuncts, there is plurality of the jīvas. When their limiting adjuncts are eliminated by discrimination, the jīva and Īsvara are realised to be identical. This truth is illustrated by way of mahāvākyas which do not differ in sense. We should take only the secondary sense of the terms into consideration.

6. THE PURIFICATION OF THE INTERNAL ORGAN.
OR
THE DIRECT REALISATION OF NADA, BINDU AND KALA

Our ignorance or impurity is an avoidable entity in that it is not absolutely real. The way to get out of impurity is by yōga, the meditation on the homogeneous identity between the jīva and Brahman. As our author blends Advaita and yōga he defines the latter in the language of the former. He says, Yōga is of two kinds: 1. Abhyāsa Yōga, 2. Jñānayōga or Rājayōga. The former leads to mantra, laya and haṭhayōga ; yama, niyama and the other six accessories are necessary for this yōga. Those of immature mental powers, says our author, can practise this abhyāsa yōga. He recommends jñāna or rāja-yōga to those of mature mental powers. Jñāna-yōga is of three kinds, 1. Sāṅkhya, 2. Tāraka, and 3. Amanaska. We have already studied Sāṅkhya yōga. Let us briefly deal with the second here.

One's food, sleep and exercise should be neither too little nor too much. In a lonely spot, the yōgin should sit in lotus posture for six hours and converge his look on the tip of the nose. In order to experience nāda, bindu and kalā and merge in Brahman, he reverses the direction of the activity of the organs. This is called mudrā, which is of five kinds : 1. khēcarī; 2. bhūcarī; 3. madhyamā; 4. ṣaṇmukhī and 5. śāmbhavī. Breath control is essential to all the signs. Nāda consists in experiencing ten kinds of sounds of varying intensities. These ten sounds constitute the first letter of "Aum", bindu, the second letter and citkalā, the third. The expressed sense of Aum is the world; its secondary sense is Reality.

Mudrābhyāsa leads to the experience of the thirty-eight kinds of utkalas in the five kinds of ākāsas, viz., 1. śabdaguṇarahitākāśa ; 2. parākāśa ; 3. mahākāśa; 4. tattvākāśa and 5. sūryākāśa. The place where these citkalās disappear is the real nature of Brahman. The yōgin should make the bindu associated with mind and the vital airs steady. For this, he has to know the nature of hamsa which is not different from the eight-petalled lotus, connected to the ṣaḍādhāra cakra. Brahman is reflected in bindu which is responsible for karma. That reflection is called Kalā. The first letter of "Hamsa" signifies Reality, the ground of nāda, bindu, kalā, the last letter mūlaprakṛti. The identity of the jīva and Brahman is revealed by m. Hamsa mantra consists in meditating upon the idea that 'I am Brahman.' After experiencing hamsa, the bindu remains steady.

Our activities and desires spring up from the movements of hamsa in relation to the eight-petalled lotus of the heart. When it leaves the lotus of the heart, it is lost in Aum.   Hamsa merges in the middle region of suṣumnā' called ājñācakra.   The aspirant has to observe the movements of the vital airs and think that he has worshipped the respective presiding deities for the prescribed number of times. The energising power of this belief purifies him.

7. MIND A NON-ENTITY

Let us deal with amanaska yōga now.   The world is the mind which is all virtues, bondage as well as liberation.   There is no necessity for the yōgin to control the organs and the mind since he realises that they are not real.   If it be said that the mind is real and that it exists in samādhi, then all the impurities of the gross body would exist in samādhi and ultimately salvation would be very remote from all the yōgins. Though the mind is denied, it will be possible for the yōgin to come back to the waking state and consequently there can be teachers and initiation. Are we not seeing saints and teachers at present ?   Samādhi becomes illusion if we do not accept the experience of the teachers.   If it be said that saints do not possess mind in samādhi for some time and do possess it afterwards when they mingle with the things of the world, then realisation would become transient.

Reality can never be tainted by the non-intelligent, impure and imperfect mind.   There is no relation between the empty mind and the positive Reality.   There is no need to control that which is sublated by Reality.   So, if the mind and the like do not come to rest the yōgin should not think that he is non-stable. Reality is known by the homogeneous vision of Anubhava-jñāna.   In the beginning of samādhi, one thinks that he is the seer and then he thinks that he is the vṛtti and then the spectator of cittavṛtti.   He goes on rejecting the vṛttis till he is merged in Brahma-caitanya which is devoid of the influence of the illusory mental modifications.

8. MEANS TO MOKSA.

The mind is essential for everything in this world.   The victory over it is the victory over the universe. Without māyā, the mind cannot function, in that the latter is of the nature of the three guṇas.   Into great difficulties are thrown all people save those devotees of māyā which is of the nature of the knowledge of identity between the Jīva and Brahman. Again, this māyā, this identity᾽ knowledge conveniently serves as a medium to transcend this very

māyā. Purity and impurity constitute the essence of the fulcrum of jīvahood. Mere outward conformity to a rule of destruction does not mean the attainment of the ideal of Perfection. A thorough revision or transformation of the whole man meets the final demand of mōkṣa. Ultimately, there is no distinction between 'good' and 'bad' 'noumena' and 'phenomena.' There is nothing like unconditional elimination or annihilation according to modern science. There must be cosmic expansion of the Self. To transcend māyā there must be sublimation in place of annihilation and sublation in place of stultification. This transcendence is affected only through Self-transcendence which leads to self-realisation.

Prārabdha karma does affect him who fails to find out Reality under the veil of the world. The wise know the world not as it appears. They are divided into four kinds : 1. Brahmavid; 2. Brahmavidvara; 3. Brahmavidvarīya; and 4. Brahmavidvariṣṭha. The first does his duties, remaining at his station. He has no desire for lust and luxury. The second renounces all duties. He has no desire nor aversion. He is the abode of as many auspicious qualities as there are stars in the sky. The third while possessing the foregoing traits, practises the native non-mental state of trance. He forgets the world like a sleepy man. He is awakened now and then, to take a little food. The fourth is awakened neither by himself nor by others. He is none but Reality. Prārabdha appears in the case of the first two. Though it is there, it cannot affect the third. It can never be found in the case of the fourth.

Renunciation, knowledge and mental tranquillity constitute the bridge to cross the sea of samsāra and ultimately get realisation. Of these three, knowledge is the supreme. Of pure knowledge the three beginning with śravaṇa are the cause, discrimination is the form and the sublation of the idea of the identity between the self and the world is the effect. He who gets pure non-attachment, self-knowledge, and mental tranquillity is known as ātmasthitaprajña. He who fails to achieve them is entangled in triangular difficulties.

Our author deviates from the account of Patañjali in regard to the accessories of yōga. He gives 15 kinds of accessories: 1. Yama consists in knowing the world not as world but as knowledge. 2. The constant regularity of realising that Reality is the seer of sense objects, is niyama. 3. Keeping aloof from the world by mind, word and deed, is non-attachment. 4. To talk not too much and to think that oneself is Brahman is silence. 5. Solitary place is that which is

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holy and uniform and which is without the activities of the mind. 6. Time is that which is devoid of ordinary time regulations. 7. Āsana is bereft of movement and bodily labour. 8. His māyābandha is destroyed who knows that prakṛti is mūlabandha (primal course of the tattvas.) 9. Dehasāmya is to merge the mental modifications in Bliss. 10. Dṛksthiti consists in knowing that the world is the cognised and the self is the cogniser. 11. Prāṇāyāma consists in breathing out names and forms and breathing in the nature of Reality while retaining inside the tranquillity of the mind. 12. Pratyāhāra is to know the real and the non-real as Brahman. 13. Dhyāna is meditation on the idea that 'I am not the body and the like.' 14. Dhāraṇa consists in making such an idea steady. 15. If all things at all times are cognised as Reality, the result is the native nirvāṇa samādhi. This is not an accessory. This is realisation, not a means to it.

9. ULTIMATE UNION.

Ultimate Union is the fruit of yōga which by actual experience possesses the knowledge of identity between the jīva and Brahman. There is nothing like becoming one with something new. It consists simply in sublimating one's own nature which is indestructible, all-pervading. So ultimately, there is no difference between yōga and advaita. Our author takes up this position and blends the two systems.

He in whom his citta is lost resembles a child and a mad man. He has no attachment to anything. Abuse and praise have no effect on him. He is always inactive like a corpse. Controlled by the powerful legacy of the past deeds, he answers the calls of the body and the like. Though the fata morgana of the world, is his abode, still, by nature, he is devoid of shelter.

He who is able to see into himself is jīvanmukta. He identifies himself with the spirit of the poor and the helpless. He remains in bondage till the fructification of prārabdha karma despite his victory over sañcita and āgāmi. He gets nirvikalpa samādhi, very often. All creatures get purified at the very sight of the jīvanmukta. He could be said to be entirely of the nature of *Sat*, if there were no body for him ...... He becomes immortal after the mortification of the body which is under the influence of prārabdha. He is known as videhamukta. There is no difference between Brahman and Videhamukta.

THE COMMITTEE SYSTEM IN LOCAL ADMINISTRATION

By

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Two fundamental principles at the back of local self-government are: firstly, independence from external control, and, secondly, giving as much opportunity as possible to the representatives of the people to take part not merely in the laying down of policies but also in actual administration. The appointment of Committees of elected members with a limited number of co-opted experts to settle the technical issues arising in the course of administration and offer advice to the local authority as a whole offers the best means of achieving these ends. The Committee System in local administration is a purely English device and, in the words of Prof. Laski, " it stands with the Cabinet and the modern Civil Service as one of the fundamental English contributions to the difficult art of self-government . . . . The success of the system has undoubtedly been due to that curious combination of amateur and expert which is characteristic of English self-government ". The happy interchange of technical knowledge and the will of the ratepayers between the officials and the members of the Committee results in the formulation of schemes which are beneficial as also acceptable to the general ratepayer. Its success has been a safeguard against that easy tendency to centralization which is the paralysis of effective self-government. For, it is in the Committees which are " the real workshops of local government " that policy is decided, resolutions are made either for immediate action or for the approval of the Council, a general control over the activities of the staff is exercised and the estimates of expenditure for the relevant departments are prepared. In short, it is in the Committees that policy is really made ; it is in the Committees also, that the supervision of its execution is really effected. The inevitable result of all this has been that, as a true organ of local government, the Council has largely ceased to function by devolving effective power on to the Committee to which it has given birth. The Council's main function to-day is

only to inform the interested ratepayer of the issues in dispute. There is nothing surprising in this, because, while in smaller units like the Parish Councils, it is possible for the whole Council to deal with all questions in detail, it has become increasingly difficult for Councils in larger units like the Boroughs to transact business without being continuously in session. Devolution of authority has become an imperative necessity and the Councils have availed themselves of the statutory method of constituting Committees to regulate and control all their activities.

I

In our country, however, the importance of the Committee System of local government has not been properly appreciated and the lack of expedition in the solution of important problems can often be attributed to the absence of a well-developed Committee system. Except in two cases which we shall refer to below, there is no provision even now, in the District Municipalities and District Boards of Madras, for constituting Statutory Committees. " A Council (or Board) may constitute committees for the purpose of exercising such powers, discharging such duties and performing such functions as it may delegate to them ". Theoretically, therefore, our local authorities could develop the committee system by constituting and delegating to committees all the powers of the Council. In a sense, this provision is even more complete and sweeping than the English provision. In England, no committee can be " authorized to borrow money, to make a rate or to enter into any contracts ". In Madras, on the other hand, no such reservation has been made in the delegation of powers, if at all, to Committees by the Council. But in actual practice, outside the Madras City, the number of Committees constituted by Councils is small and the delegations made are insignificant and it is usual to discuss the subject considered by Committees *ab ovo* in Council reducing the utility of the Committees to nil. The initiation of what policy there is, is in the hands of the Council and its execution, unhampered by any association of members of Committees, rests on the executive. In the absence of a well-organised Committee system controlling the different departments as in England where "the resolving and executive powers are fused together in the Council and delegated to Committees," the executive authority in Madras (the Municipal Commissioner or the President of the District Board as the case may be) combines in his person the functions of co-ordination between the different departments besides the execution of all the projects of the local authority.

There is provision for co-option of persons other than Councillors, with special qualifications to all the Committees. The restriction is that the number of co-opted members should not exceed one-third of the total strength of the Committees. All the provisions of the Acts relating to the duties, powers, liabilities, disqualifications and disabilities of the members of a local body apply, as far as may be, to these co-opted members of Committees. But there has been practically no co-option in the District Boards.

There is also provision for the constitution of a Joint Committee of local bodies in matters in which two or more local bodies are either jointly interested or are jointly responsible. Such a Joint Committee *must* be so constituted if so required by the Provincial Government. Outsiders possessing special qualifications or special interests may be co-opted to serve on the Joint Committee, but their number, as on the ordinary Committees, should not exceed one-third the total number of the Committee. Regulations acceptable to all the local bodies concerned will have to be drawn up for the conduct of the business at the Joint Committee. These regulations will be framed by the Provincial Government themselves when the Joint Committee comes into existence, at their discretion. In the event of differences of opinion between the local bodies in their deliberations in the Committee, the decision of the Provincial Government will prevail.

The only provision made for the constitution of Statutory Committees is in respect of appointments and contracts. "Save as provided in Sections 12-C and 72, appointments to all posts under the Municipal Council the pay or the maximum pay of which exceeds fifty rupees per mensem shall be made by a Committee consisting of the Chairman, the Commissioner and one member elected by the Council and appointments to all other posts under the Council shall be made by the executive authority subject to the rules framed by the Provincial Government." (Section 73 of M. D. M. Act). Similarly in regard to contracts, " (1) The Council may delegate to the Chairman or a Committee consisting of two or more members the power of making on its behalf any contract whereof the value or amount does not exceed one thousand rupees. Provided that in the case of municipalities included in Schedule IX or notified under sub-section (1) of sec. 12-C, the power of making on behalf of the Council all contracts whereof the value or amount does not exceed one thousand rupees *shall be exercised* by a Committee consisting of the Chairman, the Commissioner and one member of the Council elected by it; and the Council shall not exercise or delegate the power of making such contracts. (2) In respect of a contract whereof the

value or the amount exceeds one thousand rupees, the sanction of the Council for the making thereof should be obtained before the same is made. (3) Notwithstanding anything in the two preceding sub-sections, any person appointed by the Provincial Government to carry out any work into execution on behalf of a Municipal Council may, subject to such control as the Provincial Government may prescribe, make such contracts as are necessary for the purpose of carrying such work into execution to the extent of the sum applied for such work; and the Municipal Council shall pay to the person so appointed such sums as may be required for the said purpose to the extent aforesaid. " (Section 68, M. D. M. Act).

It must be said that the wording of sub-section (2) of the above clause relating to contracts does not make it clear whether it is the intention of the Act that mere sanction of the Council is necessary for entering into contracts whose value or amount exceeds Rs. 1,000 or that the Council or the Contract Committee should dispose of such contracts. All that the sub-section seems to say expressly is that the sanction of the Council should be obtained before such contracts are made. But a close reading of sub-section (1) of the clause favours the view that the Council should not merely content itself with sanctioning the contracts but also dispose of them. The difficulty lies in our ordinary conception that the disposing authority is different from the sanctioning authority. If both duties are to be vested in the same authority, then it should be made clear. Recently the Provincial Government have made it clear (by their Order No. 2661 L. & M. dated 24-6-36) that the proceedings of the Contract Committee and the Appointment Committee need not be placed before the Council since the Council is incompetent to modify them, although nothing prevents the proceedings being placed before the Council for its information. Thus these two are independent statutory committees whose views cannot be looked upon as *mere* recommendations.

A word must be said about the composition of these two Committees. They consist of three members, the Chairman, the Commissioner and one member elected by the Council. A draft rule was recently published by the Provincial Government laying down that all questions coming before these two Committees should be decided by a majority of the members present and voting at the meeting and in the case of a tie, the presiding member should have and exercise a casting vote. (G. O. No. 3836 L. & M. dated 31-8-36). But when only two out of the three members are present and there is a disagreement between them, the presiding member will carry the day by his second vote. So the Provincial Government publish-

ed another draft rule on the same day (G.O. 3837 L. & M. dated 31-8-36) prescribing a quorum of two, one of whom must be the Commissioner, for every meeting of the Committee and laying it down definitely further that "unless both or not less than two of the members present are agreed to as to the decision," the decision of the Committee arrived at shall be void. This is rather confusing. If all the three members are present, there is no trouble. No meeting can take place unless there are two members, one of whom must be the Commissioner. That is to say, the Committee cannot meet without the Commissioner. In case only one member and the Commissioner are present and there is also a difference of opinion between them and added to all this, the other member also happens to preside over the meeting, then the casting vote of the presiding member notwithstanding any decision reached is only valid if both the members present are agreed about it. Thus the casting vote of the presiding officer is useless when only two members (including the Commissioner) are present and when there is a difference of opinion between them and the Committee has to disperse without transacting any business. This difficulty has already arisen in practice, and as the Masulipatam Report for the year 1936-37 says, "Business was not generally transacted at the meetings of these two (Appointment and Contract) Committees unless all the members were present." Even when all the three members are present and " not less than two of the members present are agreed to as to the decision, " if there is a difference of opinion between the presiding officer and the other two members who agree, the former can easily bring the proceedings of the Committee to a deadlock by exercising his casting vote. Moreover, according to the draft rule, each member of the Committee may get a chance of presiding. Usually the Chairman presides, if he is present. But in the absence of the Chairman, there may be a contest as to who should preside, whether the Commissioner or the other member. Who is to decide this contest ? The question of presiding over the meeting assumes great importance, since the presiding member is the ultimate victor on all occasions of difference. The Provincial Government must soon provide against all these difficulties, lest they should lead to deadlocks in Committee work.

II

In the Madras City Corporation, statutory provision was made for the first time in the City of Madras Municipality Act of 1884, for the appointment of a Committee of eight including the President. This Committee was of an omnibus character, though in the discharge of its principal functions it approximated to the Finance

Committee of England. It was charged with the duty of checking the monthly abstracts and disbursements and was also vested with the power to conduct a monthly audit. It was responsible for the appropriation of funds for works and watching expenditure against allotments. Contracts had to be scrutinised by this Committee. Constitution of sub-committees with all the powers of the parent Committee, was also provided for. Provision was, at the same time, made for the constitution "from among their own number of such Committees consisting of such number of persons as they think fit, for the purpose of inquiring into, and reporting upon, any matter connected with the purposes of this Act." These functional Committees were not Standing Committees and had none of their attributes.

The position regarding Committees remained substantially unchanged in the Act of 1904, and it was not until 1919 that Statutory Committees were required to be constituted for (1) Taxation and Finance, (2) Works, (3) Health and (4) Education. Each of these Committees was to be composed of seven elected members with the proviso that no Councillor could be a member of more than two committees. The powers and duties of each Standing Committee were to be determined by the Council by the framing of regulations. Provision was made for joint committee meetings when the subject under consideration concerned more than one Committee. The supervision of the utilization of budget grants was a statutory duty imposed upon the Taxation and Finance Committee. Besides, this Committee was authorised to obtain the explanation of the Commissioner regarding any receipt or expenditure of the Council and charged with the duty of writing off irrecoverable amounts due to the Council and of conducting a monthly audit.

In 1936 two more Committees—one for Accounts and the other for Town Planning improvements—were added to the statutory list, and the duties of the Taxation and Finance Committee were transferred to the newly constituted Accounts Committee. Permission was accorded, for the first time, for the constitution of optional Committees, but previous sanction of Government was a condition precedent for such constitution.

Regulations framed by the Council require that no matter shall ordinarily be placed before it unless it has been considered by the Standing Committee concerned and its recommendation taken. Under the Madras City Corporation regulations, therefore, the Committees only make recommendations to the Council and do not dispose of proposals finally. This defeats, to a larger extent, the

principle underlying the constitution of Committees, and in actual practice a matter of any importance is discussed fully at the Council even though the appropriate Standing Committee has examined all aspects of the question and has arrived at definite conclusions.

The sanction of a Standing Committee is required to an estimate or a contract exceeding Rs. 10,000 but not exceeding Rs. 50,000. No contract involving expenditure of more than Rs. 3,000 may be entered into without calling for tenders unless the Standing Committee authorises such action. The Standing Committee may amend the establishment schedule before laying it before the Council; and it may frame service regulations subject to confirmation by the Council. The sanction of the Standing Committee is required for the exchange of immovable property, the acceptance of any gift burdened with an obligation, the disposal by sale or exchange of immovable property worth more than Rs. 500 and the grant of a lease for more than a year.

The Taxation and Finance Committee has been given larger powers inasmuch as all proposals involving financial outlay are examined by this Committee with reference to the recommendations of the Committees concerned. The specific statutory obligations imposed upon this Committee are two :—(1) It has to provide for payment of instalments of principal and interest due on loans outstanding; and (2) it must allow for a cash balance of Rs. 1,50,000 under the head 'General Account.' The principal difference between the English system and the Madras practice in the preparation and presentation of the budget is that in England the departmental Committees frame the estimates relating to their own departments and they may or may not be amenable to the reasoning of the Finance Committee; whereas in Madras the estimates are prepared by the Commissioner without very little, if any, consultation with the Standing Committees. The Taxation and Finance Committee has thus larger powers here and exercises the power of veto over expenditure proposed for the departments. Of course the members of the other Committees can and do criticize the budget in the open Council. But the point to note is that the English practice resembles the Cabinet system and the Chairman of the Finance Committee who presents the budget, functions more or less as the Chancellor of the Exchequer and constitutes, with the Chairman of the other Standing Committees, the Cabinet. In Madras the evolution has not proceeded so far and the reliance on the Chief Executive Officer still persists.

Appeals against taxation which were originally heard by the Taxation and Finance Committee are now heard by a special

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Committee called the Taxation Appeals Committee which came into existence under the Madras City Municipal (Amendment) Act of 1936. This Committee consists of three members, two of whom are members of the Corporation Council and are elected by it and the third who is also the Chairman of the Committee, is appointed by the Provincial Government and is paid a monthly salary. Appeals lie from this Committee's decision to the Small Cause Court.

The Mayor of the Council, by virtue of his office, is a member of each Standing Committee except the Taxation Appeals Committee.

The first noticeable feature in the City Municipal Act is the absence of any provision for co-option either to the Statutory or Optional Committees. Co-option has become a special feature of local administration in England. The reasons are: First, an elective system does not always induce qualified people to contest elections. Secondly, when they do come forward, but do not subscribe to the creed of any political party or group, they are eliminated at the polls. Thirdly, elections do not, in the majority of cases, provide the expert element necessary for administering the manifold activities of the Council. To quote the Manchester Report: "The Corporation receives the benefit of expert knowledge and advice upon many matters of a highly important and technical nature and without co-opted members, the Manchester City Council would have difficulty in manning its many Committees and sub-committees notwithstanding the fact that there are 144 elected members." Co-opted members serve two purposes: first, they keep the Committee in constant and direct touch with important organizations whose friendly co-operation is essential; and secondly, they are people who are keen on their work, expert in certain aspects of it, and generally willing and able to give a good deal of time to it.

Criticism has, however, been directed against the system of co-option. It has been contended that the privilege has not always been exercised in favour of qualified persons but on political and personal considerations. But the wording of the English Act specifically restricts co-option to specialists. The most important criticism has, however, been the financial irresponsibility of the non-elected element in formulating schemes. But this objection would be valid only if the elected councillors in the Committee fail in their duty of examining the schemes carefully. Similarly the other criticism that the experts would dominate discussions and influence de-

cisions even to the extent of an acceptance of their pet theories also rests on the relative irresponsibility and inertia of the elected element. . Even though in a small number of cases the fears of the critics have been justified, generally the system of co-option has worked satisfactorily in England. It may be reasonably expected that the introduction, in a limited form, with safeguards against abuse, of a similar system in this country would greatly assist local bodies in the solution of their many problems.

The second feature in the Madras City Act is the absence of optional Committees. But, as stated earlier, the power to constitute optional Committees is of recent origin and the disinclination to add to the number of Committees can be directly attributed to the third feature, *viz.*, the restricted scope of the Committees. The Statutory Committees here only "recommend" proposals to the Councils. The convention that all proposals should be analysed, examined in all their aspects and decision taken in the Standing Committees for the formal approval of the Council, as in England, has not evolved as yet. The result is that the disposal of business is unnecessarily impeded and the purpose of the constitution of Committees is defeated. It has to be recognised that the formulation of policy and schemes relating to a Department can be best undertaken in a small Committee which has an expert element to help the process. The Council as a whole should generally endorse the conclusions of the Committee without undue discussion over details. Equally important is the recognition that a small Committee can exercise much greater control, and in much greater detail, over the activities of a Department than the Council. Moreover, as Maud observes, members "are apt sometimes in the atmosphere of the Committee-room to forget their constituencies and the dogmas of their party and even to consider each question on its merits."

The Committee system is all the more necessary in the case of District Boards exercising several functions over a wide area. Members of these Boards are scattered over a wide area and meetings of the Board as a whole cannot be held frequently. Business has, therefore, to be transacted through committees to a much greater extent than in Municipal Councils, and the District Departmental Officers must find a place on them, preferably as Secretaries.

III

The ideal of part-time and unpaid service is not properly appreciated in this country as yet, and if it is fully understood, there can be no doubt that the technique of the Committee will certainly be found to be the pivot which makes possible the democratic opera-

tion of local government. All major decisions have to be taken in Committees composed of members who are specially equipped for the Departmental Committee to which they are appointed. Similarly all decisions taken should be translated into action through the agency of the departmental officers. It is obvious, therefore, that the Chairmen of the Committees constitute the "steelframe" of local government, and the success or failure of any aspect of local administration is indissolubly associated with the proper selection of the Chairmen for the Committees. A Chairman must have sufficient knowledge and experience of the work of the department and ample leisure to supervise and advise the officials in the execution of schemes. It must be emphasised that there should generally be very little interference with the officials over details, though often the execution of policy may bear the impress of a tactful Chairman. In short, a good Chairman has an opportunity in Committee work, that he rarely possesses in full Council, of deliberately narrowing the area of political antagonism, so that the working of a Committee may become a genuinely corporate adventure.

The role of the Departmental Chief in the activity of the Committee is no less important. Theoretically he is merely the technical officer responsible for placing plans, statistics, and reports before the Committee, for offering explanations and meeting criticism, but in actual practice his influence is considerable in the moulding of the policy. The more technical the work, the greater is the reliance of the Committee on the departmental head, and without surrendering their own discretion and the right to control these officials, the elected members should be prepared "to accept the aid of science offered them." The elected Committee "contributes common sense, an experience of the results of what the service involves, a body of general principles which set the perspective of the administrator's technique". The official, on the other hand, offers expert information and advice for the shaping of plans, the guidance of policy, and discreet and tactful criticism of either excessive inertia or over-bold experiment. This association of the official with the Committee would, moreover, obviate the habit of making the official generally the target of all attacks against bad administration.

Above all, the contact between the official and the elected members of the Committee will keep local administration "astonishingly free from the insidious vice of bureaucracy". This has been achieved, to a very great extent, in England by keeping the different heads of Departments under the direct con-

trol and supervision of the respective Committees of Council. In our country, however, this convention has not developed as yet. Even in the Corporation of Madras where the Committee system may be said to have developed to a greater degree than in the mofussil Councils, the different heads of Departments, constituting the executive of the Corporation, are subject, not to the control of the respective departmental Committees of Council, but of the Commissioner. The position of these officers is somewhat anomalous. They are answerable to the Commissioner and they exercise the delegated powers of the Commissioner. Still they are appointed by the Corporation and are liable to removal by that authority. A reallocation of responsibility is obviously necessary and only a marked development of the Committee system in municipal administration could achieve this end.

It should be noted that, under the Committee system, the Council becomes a federation of committees only and it is imperative to co-ordinate the activities of the various committees at some stage and restrict the enthusiasm of individual committees with reference to the financial implication. In England the policy of co-ordination is effected through the agency of either the Finance Committee or the General Purposes Committee. The need for keeping the rates steady or reasonably low enables, no doubt, the Chairman of the Finance Committee to control, to a certain extent, the activities of other committees. But, says Harris, nowhere has any system yet been devised of framing a unified policy, in spite of the existence of a co-ordinating committee in some of the cities of England. A similar view is taken by Prof. Laski when he says: " Co-ordination through financial control is a wholly mistaken principle unless the view be taken that there is a definable upper limit of desirable expenditure. But as long as the proceeds of a rate are so various and the needs of local authorities so different, it is impossible to discover such a limit with any precision . . . . The problems which co-ordination raises are problems of values on the one hand and of men on the other. These cannot be resolved by giving additional powers to one committee, or creating a new one, or by revising the Standing Orders. They are met by electing to a Council men of vision and insight who know how to find and to use competent officers ".

In conclusion, it is necessary to guard against certain evil tendencies of Committee work, which, if not checked in time, may lead to some undesirable consequences and even defeat the object of constituting Committees. In the first place, it should be noted

that the existence of too many committees does not permit of any co-ordination and is mainly responsible for delay in the disposal of business. Much of the time of the staff is wasted in attending to the work of these bodies. A great deal of overlapping in the carrying out of functions invariably results. The Bombay Local Self-Government Committee (1939) have drawn pointed attention to this evil. They say : " . . . . . . a number of committees are appointed and executive responsibility is divided among them. The practice generally is to find room for a number of members on one or more committees regardless of the qualifications, fitness or aptitude of the persons for the work of those committees. Chairmanships of these bodies are often offered to persons who are inconvenient just to placate them. Worse still, the posts frequently serve as pawns in the game of party politics. We find that much of the laxity in administration can be traced to this practice of dividing executive responsibility among several committees." It is, therefore, necessary that local authorities should see, even at the beginning, to the possible reduction of the number of executive committees and their separate staffs, and the merger of all functions and duties which have a common relationship, in a greater or less degree, under one committee which would naturally require a larger executive staff under the control of a responsible chief officer. Secondly, it is necessary to guard against the tendency to increase indiscriminately the number of the members of the committee. Such an increase would make the committee unbusinesslike. If the introduction of communal and regional considerations is permitted in the appointment of members to the committee, sectional interests are bound to come into play in the execution of the local body's work to its serious detriment. It is, therefore, essential that the Committee should not be unwieldy. At the same time, it is necessary that it should not be too small. For, as Laski rightly observes : " Few committees work well in which there is not a healthy division of opinion: few committees, either, work well in which the minority rests continually under a sense of grievance . . . . . and it would probably have been wise to (make) it a statutory obligation for all Councils to appoint committees in terms proportionate to party strength upon the Council ".

PALLAVI

By

P. Sambamurti

The distinctive feature of Indian Music is its rāga system. It is the foundation upon which the structure of Indian music firmly rests to-day. The rāgas afford an opportunity to the Indian musician to display his powers of creative skill. In European music, the utmost that a performer can hope to achieve is to render a classical piece in a highly polished and artistic manner and also interpret it according to his own genius. But an Indian musician, in addition to doing this is able to delight his audience with his own *extempore music*—music improvised on the spot. At least a third of the duration of a concert is devoted to the performance of extempore music. Singing or performing creative music or *manodharma* sangita as it is called indicates the highest degree of musical culture. The ideal of *absolute music* is reached in this branch of sangita. Rāga ālāpana, Tāna (Madhyamakāla) Pallavi,* Svara and Niraval are the five branches of creative music. Of these, the pallavi is the most difficult and is attempted only by experts. Manodharma Sangita is art music in its purest form.

Though the art of Pallavi-singing is hinted at in a vague manner in the *Sangita Ratnākara* of Śārngadeva (early 13th Cent.), yet it did not attain its full development until the eighteenth century. This art is unquestionably the brightest product of the South Indian inventive genius. The Pallavi is the heaviest item in a South Indian concert and contributes greatly to its scholarliness. Raga alapana is unmeasured music and pallavi is measured music. The pallavi constitutes the necessary counter-part of the long drawn-out alapana of a major rāga. The detailed alapana and the pallavi rightly occupy the central place in the South Indian concert. Pallavi is in a sense raga alapana in measured form woven round a stock theme. To be a successful pallavi singer, one must, in addition to artistic sense and imaginative faculty possess creative talents of a high order. Eminent musicians and composers in the past have distinguished themselves as

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*The term 'Pallavi' also means the first section of a song. But here we are concerned with pallavi as a branch of manodharma sangita.

great pallavi singers. Many pallavi contests have taken place in the samasthanas of Rajas and Zamindars. Posterity remembers with pride and zeal the historic events that brought forth some of the excellent pallavis which we possess now.

The term 'pallavi' is formed from the initial syllables of the three words:—Padam=words; Layam=time and Vinyasam= variations. The words of a pallavi may be either on a sacred or secular theme. The words may also be of an amorous, satirical or humorous character. Pallavis in manipravala sahityas also exist. Prathamānga and Dvitiyānga are the two parts of a pallavi and the dividing point is called the padagarbham. At this point there is a period of rest or viśrānti. The two parts may be of equal or unequal length. Major pallavis admit of a long and detailed treatment while the minor pallavis are intended for use in concerts of shorter duration.

A musician may show his talents by handling some well-known classical pallavi in an artistic manner or by composing a pallavi bristling with technical beauties and intricacies of rhythm and presenting the same to the audience. He may compose a pallavi in any raga, tala and tempo provided it otherwise satisfies the ordinary rules of musical composition. Pallavis may be composed in common ragas like Sankarābharaṇa, Bhairavi or Toḍi or in uncommon ragas like Subhapantuvarāḷi and Mandāri. They may also be composed in ragas which are known for their admittedly limited scope like Gaulipantu, Sāma and Surati. Pallavis in common tālas like Ādi, Rūpaka, Jhampa and Tripuṭa exist in plenty. A musician may cut a new path by composing pallavis in the less common suḷādi talas and in the 108 talas. Patnam Subrahmanya Iyer (1845-1902) has earned for himself undying fame by composing a pallavi in the Simhanandana tala, an avarta of which takes 128 aksharakālas or units of time. The dhatu (musical setting) of a pallavi is sometimes coloured by the introduction of changes in figure (நடை.) Pallavis involving gati bhedas and pallavis in 16 and 32 kalas are more complex. There are also pallavis in mixed tempos. The handling of such intricate pallavis with accuracy and thoroughness is a Herculean task, human capacity being what it is. Adi tala and Jhampa tala pallavis are usually of the length of one or two avartas. Rūpaka and Tripuṭa tala pallavis are of the length of either two or four avartas. Rattai pallavis (double pallavis) are an interesting variety and are unique by themselves. The whole pallavi in this case consists of two independent pallavis, perfect in themselves and melodi-

cally blended. The first pallavi naturally suggests and leads on to the second.

Sometimes we come across literary beauties like the *Svarākshara sandhi and the Gopuchcha and Śrōtōvaha yatis in the pallavi sahitya. The classic instance of a svarakshara pallavi is the famous one in Mohana raga " sariga pāgā ichchenē—sādā pāgā ichchera " where the italicised syllables are examples of svaraksharas. The wellknown Kambhoji pallavi composed in honour of H. H. Swati Tirunal of Travancore "Saguṇa nidhi chandra kulaśekharendra" admits of a treatment after the manner of gopuchcha yati thus : Saguṇa nidhi chandra, guṇanidhi chandra, nidhi chandra, chandra, kulaśekharendra. Such pallavis can be enjoyed in full only when performed.

The starting-point or eḍuppu of a pallavi may be sama (i.e., the music and the tala commencing simultaneously), atita, (i.e., the music starting before the commencement of the tala) or anāgata (i.e., the music starting after the commencement of the tala). Atita eḍuppus become a necessity in those pallavis which have a longer prathamānga. The starting-points in the atita and anagata pallavis may be on any fractional point of the tala. Atita pallavis with the eḍuppus $+ \frac{1}{4} + \frac{3}{8} + \frac{1}{2}$ and $+ \frac{3}{4}$ and Anagata pallavis with the eḍuppus— $\frac{1}{4} - \frac{1}{2} - \frac{3}{4} - \frac{7}{8} - 1 - 1\frac{1}{4}$ and $- 1\frac{1}{2}$ are well-known. Sama eduppu pallavis are relatively easier to handle.

Procedure for developing a Pallavi

When the principal performer finishes the detailed alapana of the pallavi raga, a brief period of rest ensues. During that period the Mridangam player tunes his instrument accurately and gets ready for his task. The Violinist also gets alert. The attention of the audience is all on the principal performer at this moment and they eagerly await to listen to his pallavi. The accompanists listen to him with even greater attention, because their reputation rests on the quickness with which they understand and respond to the pallavi. The first few minutes of the pallavi music are really tense moments to all excepting the performer and the audience listens to the music in pin-drop silence. Whereas the mridangam player is concerned only with the rhythmical construction of the pallavi, the Violinst is concerned with its musical setting as well. The pallavi is the most powerful weapon in the hands of a principal

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*Svarakshara beauty is a case where the Sahitya syllables happen to be also the solfa syllables and at the same time give some meaning.

performer and he can spring surprises on his accompanists by presenting intricate pallavis. With the pallavi weapon leading violinists and mridangam players in the past have been humbled before large and cultured audiences by even junior vocalists. Kachcheri dharma requires the principal performers to give all reasonable opportunities to the accompanists to grasp the pallavi. If familiar pallavis are sung, the accompanists have no need to worry themselves.

The stages in the development of a pallavi are : —

(1) *Enunciation.*—The principal performer who has the privilege to start sings the pallavi of his choice in a clear manner, pronouncing the sahitya syllables correctly and indicating in unambiguous terms, the eduppu and the distribution of the words in the āvarta. If he refrains from making any of these points clear, he is said to *abuse* his position as the principal performer. By this act of omission on his part he does grave injustice to his accompanists. On such occasions, the senior musicians and the *rasikas* present in the audience have a moral right to ask him to be fair to his accompanists.

(2) *Sangatis.*—The presentation of the pallavi with its sangatis or variations constitutes the second stage. These variations are usually variations on parts of the theme and not on the whole theme.

(3) *Niraval.*—Here the pallavi is presented in new melodic garbs, the rhythmical setting being kept intact. Niravals gradually tend to become variations on the whole theme. The singer reverts to the original theme at the conclusion of each niraval.

(4) *Anuloma* and *Pratiloma.*—Anuloma consists in keeping the tala constant and singing the pallavi at double and quadruple speeds ; as a consequence the pallavi music will be heard twice and four times respectively within the space of the original period of duration. *Pratiloma* consists in keeping the speed of singing constant, but reckoning the tala at double and quadruple speeds ; as a consequence the tala will be reckoned twice and four times respectively within the space of the original period of duration. A high degree of laya-jnānam is required to perform with accuracy the anuloma and pratiloma for a pallavi.

The above four stages relate to the development of the pallavi proper.

(5) *Kalpana svaras.*—The ideal underlying the singing or performing of kalpana svaras, as in other branches of manodharma

sangita being the delineation of the raga in all its melodic richness, a true musician delights his audience by presenting svara combinations of varied lustre and form and revealing therby the latent beauties of the raga. At first kalpana svaras of half, one, two, four and eight avarta duration are attempted and they are then followed with svaras of duration of multiple avartas. Extempore svaras coloured with jati bhedas and naḍai (நடை) bhedas are next attempted.

In order to heighten the effect and at the same time give an emphatic and ornamental finish to the kalpana svara passages, it is usual to conclude them with *makuṭams*—literally crown-like endings. These makuṭams give timely hints to the mridangam player of the approaching conclusions. Taking the clue, he accompanies the singer with vigour and the total effect is very pleasing. Short kalpana svaras are concluded with short makuṭas and kalpana svaras of multiple avartas with well-planned-out longer makuṭas. Concluding with a makuṭam is however not obligatory but is desirable within certain limits. The charm underlying some of the chiṭṭa svaras (solfa passages) adorning classical kritis like *Ni madi challaga* in Anandabhairavi is due to the beautiful makuṭams at the close.

Talented musicians sing kalpana svaras to the different words of the pallavi sahitya as well. They sometimes introduce appropriate coloured solfa passages for portions of the pallavi sahitya and the interspersed svara passages offer a welcome variety.

(6) *Ragamalika*.—Extempore svaras in different ragas are now attempted so as to form a garland of ragas. In each case the svara passage is concluded with a brief complementary svara passage in the pallavi raga and the original pallavi is then sung. Sometimes the pallavi itself is transformed into the new raga the rhythmical setting being kept intact and the svara passages are concluded with this new pallavi. After the pallavi in the new raga is sung once, a couple of avartas of svaras in the original pallavi raga may be sung and the original pallavi taken.

At the conclusion of the raga malika, a string of extempore svaras in the original pallavi raga is rendered and the pallavi sung. Thus this section of the pallavi development is brought to a formal close.

(7) *Tālamālika*.—A few gifted musicians make a talamalika of the pallavi. Here the pallavi is gradually compressed or expanded into other talas (*i.e.*, talas which differ from the original tala by a few aksharakalas) and presented. In the tala-

malika process, each new resulting pallavi may be treated as a separate regular pallavi and handled. Kalpana svaras to the pallavi in the new tala as well as ragamalika svaras to the pallavi in the new tala can be attempted.

A further variety can be obtained by making a *raga tala malika* of the pallavi, i.e., by presenting each of the talamalika form of the pallavi in a new raga as well. In fact the varieties that are possible in the sphere of creative music are unbounded and limitless.

(8) *Change of tempo.*—As a crowning conclusion, the tempo of the original pallavi is slightly quickened and sung. A few avarta madhyama kala kalpana svaras are also sung and the pallavi is formally brought to a close with a brief alapana of the pallavi raga.

In the case of solo instrumental concerts (Violin solos or Vina solos) Kachcheri dharma requires that the performer should *sing* the pallavi just three or four times so as to enable the mridangam palyer as well as the audience to grasp the pallavi. Even instrumentalists not possessing good voice should do it as a matter of course.

REVIEWS

OXFORD ECONOMIC PAPERS NO. 1. Clarendon Press (1938)
Price 3sh. 6d.

Oxford Economic Papers is a serial publication intended primarily as a channel for the publication of the results of research work carried on in the University of Oxford, and the first number contains a variety of contributions of exceptional interest and of high quality. Mr. H. D. Henderson inaugurates the series with a discussion of the highly controversial question as to the influence of the rate of interest on investment and economic activity. Is cheap money one of the dominant factors in economic recovery as has been widely held by the economists and public opinion in the past ? In answering the question Mr. Henderson has had the advantage of the results of an investigation of the Oxford Research Group who by a fairly detailed questionnaire have elicited the opinions of businessmen numbering 37 and including manufacturers in a wide range of industries, merchants and financial institutions. These results have been separately set forth at length in the second article by Mr. Meade and Mr. Andrews, and Mr. Henderson's discussion is largely based on these results.

Broadly, the opinions of the businessmen are to the effect that their activities have not been able and are unlikely to be directly affected by changes in interest rates. Indeed, even the indirect influence exerted through the change in the level of security values and consequently in their balance-sheet positions is not regarded to be of great importance. But this view is not surprising. The factors that affect investment are so numerous and their effects so unpredictable that even a considerable rise or fall in the rate of interest cannot determine the decision of the entrepreneurs. The conjectural nature of many of the estimates, e.g. trend of costs and prices, rate of obsolescence, etc., and the wide margin or error that is possible therein tend to minimise greatly the influence of a fractional change in the rate of interest. It is the expectation of higher prices rather than the cheaper terms of borrowing that induces the businessman to expand his activity.

The real question therefore is : What is the *modus operandi* by which the lower bank rate brings about better trade or high prices ? Mr. Henderson after examining various possibilities takes the view that "changes in the rate of interest may affect economic

activity through a channel different in kind from any that have hitherto been considered." They affect activity and prices through their influence on the stock exchange prices of fixed interest securities and through the consequent impetus it gives to expenditure of various kinds and to the demand for certain luxury goods. Again, on account of the problem of budgetary equilibrium in several countries, the rate of interest may play an important part in determining the volume of public expenditure which would depend largely upon the burden of interest charges. If the above argument is accepted, it would appear that the old view that the rate of interest affects vitally investment and level of activity still remains valid though on grounds different from those advanced by the economists. The question has been admirably discussed in the paper to which further attention may be drawn.

The third contribution is by Philips Brown and Shackle who have prepared an index of real turnover for the period 1919-36 for the United Kingdom. The object of the article is to study the trends of the index of real turn-over in the post-war period by " relating the total non-financial cheque payments with a specially constructed index number of prices of the goods and services for which the cheque payments were made." The index of the total Metropolitan, County and Provincial clearings (M.C.P.) was regarded as supplying an index of the total flow of cheque payments in the non-financial circulation. The limitations of this index for the purpose in view have been first discussed by the authors. Later, the relation between M.C.P. and G.N.T. (Gross National Income) is examined and the results of the comparison of M.C.P., M.C. and G.N.I. both from the table and graph are summarized in Section 4. After describing the method of calculating the composite index number of prices, the indices of real turnover for the periods 1919 to 1936 and 1929 to 1936 are calculated, and these results are graphically represented and discussed in the final section. The paper provides the economist and the business man with interesting tools of economic analysis.

The purpose of the next article on the Liquidity Preference Schedules of the London Clearing Banks by A. J. Brown is to investigate the way in which those banks have changed their holdings of different kinds of assets as the relative yields of those assets have varied during the post-war period. After a preliminary discussion of the nature of liquidity, and the form of the liquidity preference schedule the results have been set forth tentatively. It is found that banks *decrease* their liquidity preference in a slump and *in-*

crease it soon after recovery sets in and the immediate financial stringency has passed. Mr. Brown's construction of liquidity preference schedule is likely to become quite a useful instrument for quantitative investigation.

The volume concludes with a study of the measurement of the mobility of labour as between different places and its dependence on the state of trade, the type of unemployment, sex, age, type of skill and so forth. The object of the study is less to draw conclusions than to measure mobility of labour between one period and another or between different types of labour. It is true that certain interesting conclusions also emerge from the application of the technique devised by the contributors. For example, it has been found that mobility of labour tends to become greater in prosperous years, that in regions which have a high proportion of agricultural labourers mobility is high, and that textile labour is not easily transferable into other industries like the motor industry.

The first number of Oxford Economic Papers has reached a high level of performance. It embodies the results of inductive studies made by competent economists. What is even more important, most of the contributors have devised a new technique and fresh tools of economic analysis which can be made use of by others in the problems in which they are interested.

P. S. L.

PROCEEDINGS AND TRANSACTIONS OF THE NINTH ALL-INDIA ORIENTAL CONFERENCE, TRIVANDRUM, 1937. Published under the auspices of the Government of Travancore, 1940.

Indology is an entrancing and growing subject. Ever since its study was begun over a century ago by scholars like Prinsep, Cunningham and Max Muller it has attracted the attention of a good many scholars both European and Indian, and of late a large number of Indian scholars have begun to take great interest in it. The All-India Oriental Conference which was first organised in 1919 at Poona, an important seat of Indological studies, and shares largely the features of the work of the International Orientalists Congress, is a living illustration of the interest of the Indian scholars in the subject. It meets once in two years at an important cultural centre in the country. In December 1937 it held its Ninth Session at Trivandrum under the presidentship of Dr. F. W. Thomas.

The bulky and rather unwieldy volume under review is a record of the Proceedings of this session of the All-India Oriental Conference and contains a collection of important papers submitted to it. The Conference was divided into fifteen sections each under its own President. They were : (1) The Vedic including Indo-Aryan ; (2) Iranian and Zoroastrian Languages and Literature ; (3) Islamic Culture and Religion; (4) Classical Sanskrit; (5) Philosophy and Religion; (6) Prakṛts, Jainism and Buddhism; (7) History; (8) Archaeology, Epigraphy and Numismatics; (9) Ethnology and Folklore; (10) Fine arts; (11) Āyurveda and Technical Sciences; (12) Philosophy and Indian Languages; (13) Modern Indian Languages, Malayalam and other languages of South India; (14) Other Indian Languages and (15) Paṇḍita Pariṣad. More than two hundred articles were submitted to the Conference. And of them some hundred articles have been published in the volume under review classified under different sections, each prefaced by the address of the Section President.

In a short review of this kind it is not possible to refer to all the articles published in the volume and hence a passing mention is made of only some of them.

In an article in the section on Islamic Culture and Religion Prof. H. K. Sherwani examines in some detail the political philosophy of Al-Fārābi and thinks that he was definitely the first purely theoretical political scientist of the Islamic world and his views decidedly foreshadow theories such as those of social contract and sovereignty of the European thinkers who came centuries later. A description of the City-State of Mecca by Habibulla is also interesting.

In a paper published in the Sanskrit Section, Mr. Pusalker propounds the novel and improbable view that Āndhra Śūdraka was the author of the Mṛcchakaṭika and assigns him to the third century B.C. The date, birth-place and literary career of Saint Vilvamangala, the Jayadeva of South India are discussed in a paper by Ullur S. Paramesvara Ayyar who thinks that he was born in North Travancore and lived in the thirteenth century.

On the authority of *Tīrthacintāmaṇi* of Vācaspati Miśra, a jurist of fifteenth century, Mr. Babatosh Bhattacharya describes the Hindu pilgrimages of the day. The Rāmeśvaram mentioned in the work is taken to be in modern Orissa. Mr. V. A. Ramaswami Sastri shows in an article that Bhartṛhari was one of the earliest Pre-Śaṅkara exponents of the doctrines of the Advaita system of philosophy.

In the History Section Mr. V. R. Ramachandra Dikshitar's account of the Āyi Kings, a small local dynasty of rulers that held sway for a considerable time in portions of the modern Travancore State, shows the importance of the study of local history. Dr. M. Rama Rao discusses the rise of the Kākatiyas and thinks that the Kakatiya kingdom had an Eastern Chalukyan origin which appears to be sound. In a paper Mr. V. V. Mirashi examines the Kalacuri-cedi era and concludes that it commenced on the 6th of October A.D. 248. Mr. H. C. Ray Chaudhuri's discussion of the term *Audbhijja* as a dynastic description is interesting. Dr. N. P. Chakravarti's account of the life and work of James Prinsep, the originator of Indian archaeological studies forms a fitting epilogue to the section on Archaeology.

The section on Ethnology and Folklore contains some interesting articles. Mr. Gopala Pillai's attempt to identify Skanda of the Indian literature with Alexander and trace the references that lie scattered over the whole range of Indian literature to the conquest of Alexander the Great, and the description of Gaṇeśa as a corn-deity by Mr. Lacchimidhar Shastri are among the most 'original' contributions in this section.

Except for its somewhat unhandy size the volume is produced in a manner worthy of the Travancore State Government under whose auspices it is published.

T. V. M.

THE TRAVANCORE TRIBES AND CASTES. By L. A. Krishna
   Iyer. Pp. liv. and 344 with 108 maps, plates and charts. (Trivandrum : Government Press, 1939.)

This volume contains an account of eight of the tribes of the Travancore State, namely, Muthuvan, Nayadi, Paliyan, Paraya, Pulaya, Ullatan, Urali and Vishavan. Baron von Eickstedt of the Breslau University contributes an introductory chapter on "the history of anthropological research in India" which he uses partly to restate his conclusions on the racial composition of the Indian people, partly to answer the criticism of his hypothesis by Dr. B. S. Guha who covered nearly the same ground at the time of the census of 1931. Von Eickstedt's efforts to clarify the issues in Indian race nomenclature will be welcomed by all students of physical anthropology. We shall be looking forward to details on many a moot problem, such, for example, as the explanation of the brachycephalic element in Western, Southern and Eastern India, the question of

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the Negrito strain in the tribes of the Western Ghats, etc., which are promised in a forthcoming publication by the German savant. Mr. Iyer's last chapter on the physical anthropology of the tribes of Travancore contains references to the controversy about the Negrito strain in India. What we want is definite data about such tribes as the Uralis, but unfortunately, the photograph of the Urali woman (opposite page 285) with a large mop of hair is too dark to show any detail. A carefully prepared section of her hair would have been also useful. As von Eickstedt points out, the terms 'frizzly' 'kinky' etc. should be used carefully. Photographs however are often a good corrective against the personal equation of observers, as also the use of a good type of "hair chart."

The sociological part of the volume follows the survey method popularised during Risley's ethnographic survey. Mr. Iyer gives his readers a good insight into the culture and manner of life of his tribes. Each of his chapters, will, we hope, be enlarged later on into a monograph so that detailed analysis can be given of many of the author's generalisations. Mr. Iyer, for example, draws a parallel between the matriliny of the Muthuvans and that of the Melanesians in that the *potestas* of the father cuts across the authority of the mother's kin, but in the absence of details, one is not in a position to decide if the resemblance is merely superficial or if it goes deeper.

It is regrettable that the author has not followed any recognised system of transliteration of Malayalam words. What can, for instance, a foreign reader make of *Nathune* ?

In spite of a few slips here and there, the printing and get up are a definite improvement on those of the first volume of the work.

A. AIYAPPAN

SANGA ILAKKIYAM, Published by the Saiva Siddhānta Mahāsamājam, Madras, 1940, pages xxxii+1526. Price Rs. 3-4.

This handy edition of the classics of the Tamil Śangam, the *eṭṭuttogai* (eight anthologies) and *pattuppāṭṭu* (ten idylls), will be welcomed by all students of Tamil and fulfils a longfelt want. Among the scholars that have laboured in the field of Śangam literature, they are not many, Dr. V. Swaminatha Aiyar stands foremost, and his scholarly editions of several of these works have played a great part in promoting the study and appreciation of these poems by students of the language, literature and history of the Tamil people. And the S. S. Mahāsamājam has now provided the growing number

of such students with a handy and beautiful edition of the texts which, it is understood, will soon be followed by a comprehensive subject index to all the poems included in this edition.

This edition is based on a fresh study of the manuscript material (listed at pp. xxi-xxvi), and this study has resulted in numerous textual improvements, and none can afford to neglect this new text in any study of the language, metre and so on of these poems. The chief feature which distinguishes this edition is the grouping of the poems according to their authors, the authors themselves being arranged in an alphabetical order. All the necessary bibliographical aid is provided by a series of carefully prepared indexes which set forth (a) the missing poems some of which have been recovered and published for the first time here (b) the traditions relating to the origin, authorship, collection etc. of the poems (c) the printed editions of the different anthologies (d) the titles of the different chieftains etc. (e) concordances between the present edition and the anthologies (f) the persons celebrated by every poet and the poets celebrating every ruler or chieftain named and so on.

No name appears on the title page except that of the Mahāsamājam, but a perusal of the learned and eloquent preface contributed by the energetic Honorary Secretary of this organisation, Mr. M. Balasubramanya Mudaliar, B.A., B.L., shows that the idea of this edition was started nearly seven years ago, and much preliminary work was done by the Secretary himself and several other scholars for some years by way of collecting manuscripts and collating them with one another and with the printed editions already in existence. We also learn that Rao Saheb S. Vaiyapuri Pillai has done so much work for it that he should be considered its virtual editor, a fact which in itself is a guarantee of the accuracy of the edition before us. It should also be mentioned that the cost of the edition has been borne by Mr. T. K. Narayanaswami Naidu who has always evinced a very enlightened and generous interest in the work of the Samājam.

In spite of a not inconsiderable list of errata (pp. xxvi-xxx)—some of the entries here are not corrections of errors but conjectural emendations of the text—the book is a marvel of cheap and efficient book production.

K. A. N.

ANNUAL REPORT OF THE ARCHAEOLOGICAL DEPART-MENT, BARODA STATE, FOR 1937-38.

The report is a record of very useful work and does great credit to the scholarship and enterprise of Dr. Hriananda Sastri, the Director of Archaeology in the State. Among the monuments conserved, mention may be made of the Rāma temple of Bardiā and the Rāni Vāv (well) and the tomb of Shaikh Farîd at Pāṭaṇ. The Department surveyed a number of ancient monuments among which the Hiṅglōjī Māta temple of Khaṇḍran dedicated to Sarvamaṅgalā, the Śiva temple of Āsodā and the Kōṭyarka temple of Mahuḍī deserve special mention as structures of high artistic value. The first two monuments belong to the 13th and 12th centuries respectively. On the Epigraphical side, 36 inscriptions were copied, five being Muslim and the rest Hindu, of which one is a late Brāhmī piece while the others are of a miscellaneous character and range in dates from the 14th century to the 18th. Excavations carried on near Amreli yielded pottery resembling the glazed pottery of the Mauryan times.

But the most interesting part of the work done by the Department is on the side of art. From the Kōṭyarka temple at Mahuḍī were recovered four bronzes, three of which represent the Buddha, one with Kubēra and Hārītī, another under a seven-hooded cobra with a Yaksha and Yakshiṇī seated on a Nāga and Nāginī respectively and the third with Kubēra. Among the sculptures obtained by the Department, special mention must be made of the figure of Vishṇu-Trailōkyamōhana riding Garuḍa and a ceiling pendant from old Pāṭan which contains exquisite carvings. The Department also prepared drawings of mural paintings of the 17th and 18th centuries. The report contains, appended at the end, 16 plates representing the antiquities mentioned above.

M. M. R.

PROCEEDINGS OF THE CONFERENCE ON EXAMINATIONS AT DINARD (FRANCE) 1938.   Edited by Paul Monroe. Bureau of Publications, Columbia University, N. Y.

Examinations have been notoriously the subject matter of controversy of an acrimonious kind, especially in recent times. The standards and devices employed, the methods of valuation and assessment, the part played by the predilections of the examiner, the general lack of objectivity in the whole business, have all been severely criticized and much material has been accumulated which

shows a lack of consistency and validity in the system of examinations in vogue at the present day. The ' essay-type ' examination in particular has been subjected to the criticism that it does not lend itself to precise assessment, the 'essay' being an extremely intricate and complex product always. During the last war, in the U. S. A. the recruiting authorities made use of what are called " Intelligence tests, " the favourite for some time in France as well where they originated. They were concerned to have tests which could be quickly and rapidly applied and "Intelligence tests " came extremely handy. There has been, however, no general adoption of these Tests elsewhere and the 'essay-type' examination has not yet been displaced.

Still the existing position has been recognized to be extremely unsatisfactory. Investigation and experimentation here and there have been proceeding, in search of a satisfactory substitute for examinations. It was with the object of drawing together these investigations and organising them on continuous and systematic lines that Dr. Paul Monroe entered the field, having persuaded the Carnegie Endowments authorities to finance the enterprise.

Several national committees were set up and conferences held of competent investigators in the field and the volume under notice is the record of the proceedings of the most recent of them, held at Dinard in France. Eminent educationists from the old world and the new participated in the discussions and we have in this volume the text of the contributions made by Dr. Spearman, Thomson, Sadler, Ballard, Zilliacus, Thorndike, Bougle etc.

The central educational problem of our times is to avoid wastage of effort by conscious, effective adaptation of the educational technique and process to the ascertained differences of individual ability. To the end that these differences may be accurately ascertained, examinations have been employed hitherto—but, as has been generally admitted, unsuccessfully. The factors vitiating the examinations have been numerous and scarcely susceptible to complete elimination or neutralization. Absolute precision of assessment is not necessary and is indeed not easily attainable. The conference did not set itself the task of discovering a precise measure which all countries could straightway adopt. Indeed it could hardly have succeeded if it had set itself any such task. But one notes with disappointment that even after the lapse of so many years, exploration is still going on and the constructive part of it receding into the distance. The present volume is source-material rather than a constructive document. Rational correlation of the experience

so far gathered has, one fears, been already too long delayed. May we not hope that ere long the constructive guidance we have a right to expect from so well-conducted and important an investigation will be forthcoming ?

<div align="right">S. R.</div>

ECONOMIC DEVELOPMENT, VOL. II.   By B. K. Sarkar Chuckervarty Chatterji & Co. Ltd., Calcutta. Price Rs. 6/-

Mr. B. K. Sarkar, in this book as in many of his previous ones, has shown himself an extremely painstaking and industrious gatherer of facts.   But one wishes he realised that all facts are not 'born and created equal.'   And further, that mere compilations of facts centering round a few topics will not constitute 'studies' of those topics. One has a right to expect in a 'study' of a topic, critical discussion. A bare narrative of facts is not a 'study' by any means.

The topics Mr. Sarkar covers in this volume are undoubtedly interesting and some of them are important.   Among them are the account given of the law regulating foreign enterprise in the field of Insurance, in countries like Germany, France, Italy etc., of the growth of Bank capitalism in young Bengal, of the evidences of rationalization in Indian business enterprise etc.   Of less immediate interest to Indians are essays on the post-War reorganisation of the Central Banks of France and Germany and on the bearings of the world crisis on the regions of the second and first industrial revolutions.

Mr. Sarkar's account of the European Insurance law is a conclusive answer to the interested crisis of our recent Insurance Act in that it shows the great moderation with which the Indian Government has dealt with the matter of foreign enterprise. The development of a more modern technique and the abandonment of the excessively diffident attitude now obtaining are considered essential to further progress in Bengali banks by Mr. Sarkar.   It is distressing to note in this essay, as in much Indian writing on such topics, a narrow, parochial and provincial outlook. Mr. Sarkar in his essay on evidences of Rationalization in Indian enterprise, gives a wider meaning to ' rationalization ' than is generally given to it.   This is perhaps not altogether right.

As has already been said, Mr. Sarkar is stronger in facts than in analysis of them. He would have done far better if he had kept the facts more in the background and given us a coherent, critical . account of the results of his study of them.

<div align="right">S. R.</div>

THE SOCIAL AND ECONOMIC IDEAS OF BENOY SARKAR,
edited by Banesvar Dass, Calcutta, (published by Chucker-
varty Chatterjee and Co., Calcutta, 1939, Price Rs. 8).

Professor Benoy Kumar Sarkar is a prolific writer. He has to
his credit a number of books besides several articles contributed to
different periodicals. He has made culture history his special field.
The editor of this work has taken enormous pains to present in one
volume the social and economic ideas of Professor Sarkar, and in
this he has been helped by a number of collaborators. A perusal
of the volume will show the amount of Professor Sarkar's literary
output, and the great work he has done for the cause of educational
progress in Bengal.

The volume opens with an article on the fundamental problems
and leading ideas in the works of Sarkar. His views on currency
and tariff questions as also on Indian economic problems will be
read with interest. Much more interesting are his studies on as-
pects of social eugenics and sociology. As Dr. N. N. Law points out
in his Foreword, in order to understand Prof. Sarkar as a man and
get his ideas in the most concise form 'one would naturally begin
the book with ' The Seven Creeds of Benoy Sarkar ' by Mrs. Ida
Sarkar'.

V. R. R. DIKSHITAR.

A STAGE ' A ' GEOMETRY. By L. R. Spensley and E. N. Law-
rence. Macmillan & Co., Ltd., 1940. Price 2 sh.

This is a small book dealing with the most elementary proper-
ties of lines and angles and a few elementary constructions. It con-
tains only a small amount of deductive matter and is obviously in-
tended for beginners.

The most notable feature of the book is the method of treat-
ment of the subject adopted by the author, which is quite novel and
interesting. Difficult situations and applications have carefully been
avoided. The ideas have not been presented in the usual dry and
formal manner. Every fundamental concept has been explained
clearly and with suitable illustrations from practical life. The
treatment of parallel lines, loci, and congruency deserves special
praise.

Besides, the way in which the exercises have been planned and
arranged is such as will create in the learner a real love for the

subject.   He can help himself and learn the basic principles and facts without much help from his teacher.

The authors have introduced a few new terms, viz., 'Altered angles', 'Concave Polygons' in place of 'Interior angles on the same side of the transversal,' and 'Reflex Polygons,' which cannot escape the teacher's notice.

The authors have to be congratulated on the production of a book of this kind as I am strongly of opinion that Mathematics will not prove a bugbear to a learner provided the authors of text-books on the subject adopt the method of treatment followed in this book.

G. V. N.

JOURNAL OF

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UNIVERSITY NOTES

Personnel.—His Excellency Lord Erskine, G.C.I.E., Governor of the Presidency of Madras, continued to hold the office of the Chancellor of the University till the 12th March 1940 and thereafter His Excellency Sir Arthur Hope, G.C.I.E., M.C., became Chancellor.

The Hon'ble Sri C. J. Varkey, M.A., M.L.A., who became Minister for Education in the Government of Madras on the 7th January 1939, held the office of Pro-Chancellor of the University till the 30th October 1939 when the Ministry resigned and His Excellency the Governor assumed the administration of the Province.

Diwan Bahadur S. E. Runganadhan, M.A., continued to be the Vice-Chancellor of the University up to the 10th April 1940 and proceeded on leave till the 20th May 1940, when the term of his office expired. Sri Rao Bahadur A. Lakshmanaswami Mudaliyar, B.A., M.D., F.R.C.O.G., acted as Vice-Chancellor in an honorary capacity for the above period, and His Excellency the Chancellor has appointed Sir Mahomed Usman, B.A., K.C.I.E., M.L.C., as permanent Vice-Chancellor from the 21st May 1940.

Mr. William McLean, M.B.E., J.P., M.A., B.L., Chartered Secretary, the Registrar of the University, was on leave out of India from the 11th May 1939 to 28th September 1939. During this period Sri C. R. Ganapati Pillai, B.A., Chief Superintendent of the Office, acted as Registrar.

Authorities and Meetings.—There were two meetings of the Senate and two meetings of the Academic Council during the year; the Faculty of Arts met once and the Faculties of Oriental Learning and of Science met once and twice respectively; ten ordinary and two special Meetings of the Syndicate were held.

Convocations of the University for conferring Degrees on Graduates were held on the 4th and 5th August 1939 and on the 24th February 1940. At the Main Convocation held on the 4th August 1939 His Excellency the Chancellor presided, and the address to Graduates was delivered by the Hon'ble Sri C. J. Varkey, M.A., M.L.A., the then Minister for Education and Pro-Chancellor of the University. The Pro-Chancellor presided at the Convocation held on the 5th August 1939 and the Vice-Chancellor at the Convocation held on the 24th February 1940.

The number of persons that took the several Degrees at the Convocations was: —

B.A.—1010. B.A. (Hons.)—136. M.A.—87. B.Sc.—175. B.Sc. (Hons.)—37. M.Sc.—10. D.Sc.—3. B.L.—245. M.L.—5. M.B. & B.S.—105. M.D.—2. B.E.—49. L.T.—296. B.Sc. (Ag.) —34. B.O.L.—8. B.V.Sc.—1. D.Litt.—1; and M.Litt.—1.

There was a special meeting of the Senate on the 27th October 1939 for the award of Titles and Diplomas to persons who had qualified for the same. The number of persons who took the several Titles and Diplomas at the special meeting of the Senate was: — Śiromaṇi—59, Vidvān—190, Afzal-ul-Ulama—6, Munshi-i-Fazil—21, Adib-i-Fazil—2, Diploma in Economics—6, Diplomas in French and German—17, Diploma in Gynaecology and Obstetrics—10, Diploma in Geography—7, Diploma in Indian Music—7, Diploma in Politics and Public Administration—17 and Diploma in Librarianship—2.

Laws of the University: *Statutes.*—Certain alterations in and additions to the Statutes were made authorising the payment of University contribution to Provident Fund in the case of employees on probation, and allowing a subscriber to make revised declarations from time to time. Scholarships for training in Navigation or Marine Engineering in the Indian Mercantile Marine Training Ship *Dufferin* were thrown open to candidates standing highest in the qualifying examination and domiciled within the University area, due regard being given to poverty.

Ordinances.—Additions to and alterations in the various Ordinances were made in regard to the last date for publication of the results of Examinations, dates for payment of examination fees, etc., for the B.Sc. (Pharmacy) Preliminary and Final Examinations in view of the two examinations held in a year; the 1st August was fixed as the last date for the receipt of applications for exemption from the production of attendance certificates for the Oriental Title Examinations ; Bengali was made a second Language for the Matriculation Examination; a candidate who has passed the Matriculation or Entrance Examination of an Indian University or who has been declared eligible by a University in an Indian State other than Cochin and Hyderabad will be henceforth admitted to a course of study in the University without a scrutiny of the marks obtained at the respective examinations provided that similar recognition be granted in the other University or State concerned.

Regulations.—Alterations in and additions to the Regulations were made (1) providing for a new clause stating the reason for

leaving the college in the Transfer Certificate; (2) extending the duration of papers in Science subjects under Part III of the Intermediate Examination from 2 to 2½ hours each; (3) making provision for B.Sc's in Mathematics (Main) appearing for the M.A. Degree Examination in Mathematics; (4) granting recognition to examinations of other Universities on a reciprocal basis; (5) insisting on the restriction of subjects imposed on candidates of this University applying also to candidates of other Universities; (6) restricting graduates of other Universities from appearing for the examinations of this University unless they put in two years residence within the University limits or area prior to the date of their application for the examination or Degree; (7) limiting the award of the Degrees of D.Litt. and D.Sc. to the graduates of this University; (8) providing for recognition by the University of the Supervisor and the Institute attached to another University for the M.Sc. Degree in subjects where facilities are not available here for the pursuit of higher studies by the graduates of this University. The regulations governing the M.B. & B.S. Degree were completely revised consequent on the lines recommended by the Medical Council of India, the Madras Medical Council and the Principal, Medical College, Madras. Certain minor alterations were also made in the Regulations governing the other Degree Examinations, *viz*, to include Bengali in the list of languages prescribed for the various examinations of the University; to enable teachers employed in the Schools recognised by the Education Department of the Hon'ble the Resident at Hyderabad (Deccan) to apply privately for the Matriculation, Intermediate, B.A. and M.A. Degree Examinations as *bona fide* teachers; to reduce the minimum for a pass under Part I of the B.O.L. Degree Examination to 35%; to separate the optional subjects for the Examination for the Diploma in Geography; to make the study of Indian History compulsory under Group (iv-b) of the B.A. Degree Course; to enable Bachelors of Arts (in Science subjects) and Bachelors of Science of not less than seven years standing to supplicate for the D.Sc. Degree; to exempt those who have qualified for an Oriental Title only from the operation of the time-limit of three years and to permit persons who have passed the several parts of the B.O.L. Degree Examination on different occasions but without the avowed object of taking the B.O.L. Degree to qualify for the Degree.

Constituent and affiliated Institutions.—The following colleges ·in the Travancore State ceased to be affiliated to this University from the academic year 1939-40 : —

Law College, Trivandrum, Women's College, Trivandrum, C.M.S. College, Kottayam, Scott Christian College, Nagercoil, Union Christian College, Alwaye, and St. Berchman's College, Changanacherry.

The College of Arts and the College of Science, Trivandrum, now having the final year Honours Course under the Regulations of this University, will cease altogether to be affiliated to this University from the academic year 1940-41.

The Third Quinquennial Report on the condition of Affiliated Colleges (1934-39) was adopted by the Senate in March 1940 and submitted to the Government under Section 53 of the Madras University Act. In view of recent University developments in South India, no new University centres have been recommended.

The Syndicate has resolved that a report on the condition of Constituent Colleges be prepared and submitted to the Senate. At the request of the Syndicate the Vice-Chancellor inspected all the Constituent Colleges other than the Madras Medical College and the Stanley Medical College.

The following colleges secured further recognition or affiliation in the subjects noted against each with effect from the next academic year, 1940-41:—

1. Loyola College, Madras—Kannada under Part II of the Intermediate and B.A. Degree Courses.

2. Pachaiyappa's College, Madras—Intermediate—Part III—Natural Science, Electrical Engineering and Mechanical Engineering and Group (D)—Tamil & Sanskrit; B.A. (Honours)—Branch I—Mathematics; B.Sc.—Part I—English, Part II—Physics and Chemistry (Main and Subsidiary) and Mathematics Subsidiary; B.O.L. and Vidvan under Regulation 7-D—Tamil alone. The fresh recognition was necessitated by the migration of the College from George Town to its new habitat in Chetput.

3. Theosophical College, Madanapalle—B.A.,—Part II—Kannada.

4. St. Aloysius College, Mangalore—Hindi under Part II of the Intermediate and B.A. Degree Courses.

5. Zamorin's College, Calicut—Natural Science under Part III of the Intermediate Course.

6. Government Brennen College, Tellicherry—Arabic under Part II of the Intermediate course.

Matriculation Examination as entrance test to University Courses of Study.—The Syndicate considered the question of having the Matriculation Examination as the entrance test for admission to a University course of study. The question of having a joint Matriculation Examination for all the Universities in South India was also considered. Further consideration of the question of a joint examination was deferred, owing to the difficulties anticipated in Mysore and Trivandrum as regards teaching certain subjects in the mother tongue of the students. On a suggestion made by Government, the Syndicate has decided to postpone giving effect to its decision to revive the Matriculation Examination as the sole entrance test for admission to University courses of study till the year 1945.

Teaching of non-language subjects in the mother-tongue.—On a reference from the Inter-University Board regarding the teaching of non-language subjects in the college classes in the mother-tongue of the students, the colleges were informed that if a college gives instruction through the medium of an Indian Language in any group of optional subjects in the Intermediate Examination in the first instance and if timely report is made to the University, it will make suitable arrangements for the examination of the candidates from such colleges.

Physical Education—Degree or Diploma Course.—The Senate recommended the institution of a Degree in Physical Education in the University and the Syndicate appointed a committee to consider the subject. The committee recommended that a Diploma Course in Physical Education be instituted in place of a Degree Course, relating it with the L.T. Degree Course by providing Physical Education as one of the optional subjects for the L.T. Degree Course. The matter has been referred to the Board of Studies in Teaching.

Tamil Lexicon.—The publication of the final part (Part III) of the Addendum to the Tamil Lexicon was completed by the 31st December 1939. Arrangements are in progress for a concise Tamil Dictionary based on the Tamil Lexicon being published at an early date.

Vacation Lectures for Rural Workers engaged in Social Amelioration.—When considering the institution of an Extension Board to inaugurate a programme for Adult Education as resolved by the Senate, the Syndicate decided that a course of vacation lectures by persons having experience in rural amelioration work be arranged in mofussil centres. A course of vacation lectures was delivered at

each of the following centres—Saidapet, Madura, Coimbatore, Calicut, Anantapur and Chittoor. Dr. De Valois of Katpadi, Sri K. G. Sivaswami and R. Suryanarayana Rao of the Servants of India Society and Officers of the Department of Agriculture delivered the lectures.

Prizes for the encouragement of publication of works on Modern Subjects in Dravidian Languages.—The Syndicate, on the recommendation of the Boards of Examiners, has awarded the prizes to the authors of the following books for 1939-40:—

1. "Minsarathin Vindai" (Electricity).—Mr. P. N. Appuswami—(*Tamil*).
2. "X-Rays and their application to Medicine and Science"—Mr. U. Raghavendra Acharya—(*Kannada*).
3. "X-Rays and their application to Medicine and Science"—Mr. P. Rama Pisharoti—(*Malayalam*).
4. "Nabho Vani" (Wireless).—Mr. M. R. Balakrishna Warriar and Mr. M. V. Chacko—(*Malayalam*).

Teachers and Research Departments.—Sri B. M. Tirunaranan, B.A. (Hons.), Junior Lecturer in Geography, left the University service on his appoinment as Lecturer in the Madras Educational Service.

Rao Sahib S. Vaiyapuri Pillai, B.A., B.L., and Sri R. P. Sethu Pillai, B.A., B.L., the Reader and Senior Lecturer respectively in the Department of Tamil were confirmed in their appointments from the 1st August 1939.

The post of Senior Lecturer in the Department of Kannada has been vacant from 1st August 1939.

Sri K. V. Venkatasubrahmanya Ayyar, B.A., M.L., Professor, Law College, Madras was appointed Special Lecturer in Indian Constitutional Law for the Diploma Course in Politics and Public Administration for the year.

Mr. E. Divien, B.A. (Hons.) and Mrs. Ellen N. Sharma, M.A., M.Ed., continued to hold their appointments as Lecturers for the Diploma Courses in French and German respectively.

A review of the work of the various Departments of the University for the quinquennium 1933-38 was made by expert committees appointed for the purpose and programmes of work based on the recommendations of the committees for the next quinquennium 1939-44 were submitted by the respective Heads of the Departments

and approved by the Syndicate. The reports of the committees indicate that the work done in the Departments was generally up to the mark and according to a well-planned programme.

Publications.—The following works of the members of the Teaching and Research Departments were published by the University during the year : —

Name of the work.	Author.	Department.
Uṇādi Sūtras, Part IV	Dr. T. R. Chintamani	Sanskrit
Veḷugōṭivārivamśāvali	Dr. N. Venkatarama- nayya	Indian History
Foreign notices of South India	Prof. K. A. Nilakanta Sastri	do.
Indian Agricultural Statistics	Dr. P. J. Thomas and N. Sundararama Sastri	Indian Economics
Śabdamaṇidarpaṇa	K. Venkata Rao and H. Sesha Ayyangar.	Kannaḍa
Nawabs of Carnatic, Vol. II	Dr. S. M. Hussain Nainar	Arabic, Persian & Urdu
Āṭṭakkatha	Dr. C. Achyuta Menon and Sri P. Krishnan Nayar	Malayāḷam
Bulletins		
Dravidic Pronouns	Sri V. Venkatarajulu Reddiyar	Tamil
Kayātaram	Rao Sahib S. Vaiya- puri Pillai	do.

Lectures.—Besides the annual lectures delivered by the Heads of the Departments of the University and the lectures delivered by Honorary Readers in their subjects, the following lectures were delivered during the year : —

I. SPECIAL LECTURES

1. Dr. Maria Montessori, the Italian Educationist—Three Lectures on (i) " The Psychology of the transmission of Culture "; (ii) " An Introduction to the Teaching of Algebra "; (iii) " An Introduction to the Study of Language."

2. Professor Harold Hotelling of the Columbia University (U.S.A.)—Three Lectures on "Recent Advances in the Theory of Prices."

II. Endowment Lectures.

Name of the Endowment.	Name of the Lecturer.	Subject of the Lectures.
The Maharaja of Travancore Curzon Lectureship — Engineering.	Sri P. Venkataramana Raju	Roads in Holland Reclamation of the Zuyder Zee in Holland.
The Maharaja of Travancore Curzon Lectureship — Agriculture.	Sri K. C. Ramakrishna Ayyar	Economic Factors in Agricultural Development.
The Sankara-Parvathi Lectureship.	Dr. K. N. Venkatasubba Sastri.	The History of Dharma as a Political Ideal.
The Sir Subrahmanya Ayyar Lectureship.	Dr. N. Venkataramanayya	Rudra Śiva
The Sir William Meyer Lectureship.	The Rev. P. Carty, S.J.	Some aspects of Social Economics.
The Principal Miller Lectureship.	Sri P. Narasimham	The Individual in Progress.
The Dr. Elizabeth Matthai Lectureship.	Dr. M. B. Prabhu	Diseases and Disorders of the digestive system in childhood.
The Sundaram Ayyar-Krishnaswami Ayyar Lectureship.	Sri S. Venkataraman.	Paramountcy — Its Evolution and Application
The Diwan Bahadur K. Krishnaswami Rao Lectureship.	Mahamahopadhyaya Prof. S. Kuppuswami Sastriyar.	Compromises in the History of Advaitic Thought

University Library.—The total number of volumes in the Library is 109550 of which 90555 are in the Main Library and 18995 in the Departmental Libraries. 2813 volumes were added during the year.

In accordance with the resolution of the Syndicate the printing of the Library Catalogue was continued and the following volumes have been published: —

Supplement Catalogue for 1938; Science (General), Natural Science (General), Biology, Engineering, Chemistry and Technology and Geology.

3125 volumes have been catalogued during the year involving the preparation of 7955 cards.

New Endowments.—The following new endowments were accepted during the year :—

1. From Sri M. S. Sundararajan, the executor of the will left by the late Sri R. Tatachariar, an endowment of Rs. 5,661-12-1 for instituting a scholarship to be called " the R. Tatachariar Scholarship" to be awarded to the student of the Vaishnavite Vadagalai Brahmin Community reading in the college classes for proficiency in the Kannada Language or for research in that language.

2. From the Governing Body of the Young Men's Indian Association, Madras, an endowment of Rs. 3,000 invested is 3½% Government Securities for instituting a lectureship in the name of the late Dr. Annie Besant on a subject connected with Politics or Civics or Sociology or Religion or Ethics or Philosophy or Education or Fine Arts.

3. From Srimati Padmasini Bai, an endowment of Rs. 2,000 invested in 3½% Government Securities for the award of two Scholarships to be called "the Srimati Padmasani Bai Scholarships" each of the value of Rs. 35 (per annum) to be awarded on the basis of merit and poverty to students of the Diploma Course in Indian Music.

4. From Sri J. M. Cotelingam, an endowment of Rs. 2,200 invested in 3½% Government Securities for the award of a gold medal called "The J. P. Cotelingam Memorial Gold Medal" of the value of Rs. 75 to the candidate who stands first among the successful candidates in the L.T. Degree Examination obtaining a first or second class at the first appearance after undergoing the prescribed course of study in a constituent or affiliated college.

Research Degrees.—The names of persons who qualified for higher (Research) Degrees and of the theses submitted by them during the year are given below: —

MASTER OF LETTERS.

1. Mr. Syed Sha Ali Hussain, B.A., L.T.: "Co-operative Land Mortgage Banks in Madras."

2. Mr. K. J. Jacob, B.A. (Hons.): "Madras District Administration under the East India Company."

DOCTOR OF LETTERS.

1. Mr. K. R. Srinivasan, M.A.: "Lytton Strachey: A critical study."

2. Mr. C. Narayanan, MA., Ph.D.: "Shakespeare Criticism: An essay in Synthesis."

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MASTER OF SCIENCE.

1. Mr. K. Raghavan Nayar, B.A. (Hons.): "Some researches in theoretical and applied statistics."

2. Miss V. Ammalukutti, B.A.: "Orientation of the NO_2 group and the halogens in 8_1 methoxy and 8_1 hydroxy coumarins."

3. Mr. T. S. Krishnan, B.A.: "An experimental study on the metabolism of elementary sulphur, sulphate sulphur, and organic sulphur in the animal organism."

4. Miss V. K. Kamalam, B.Sc. (Hons.): "The effect of O_2 and CO_2 on absorption of water and transpiration.

5. Mr. G. Venkataraman, B.Sc. (Hons.): "The Ecology and seasonal succession of the Algal flora of the river Cooum at Madras with special reference to the Diatomaceae: A systematic account of South Indian diatoms."

6. Miss Gunavati Mahadevan, B.Sc. (Hons.): "Preliminary observations on the structure of the Uterus and Placenta Scoliodon sorrakowah and Scoliodon palasorrah."

7. Miss K. P. Nalini, B.Sc., (Hons.): "Observations on the Nidamental organs (glands) of *Chiloscyllium* griseum (Mull and Henle).

8. Miss C. K. Ratnavati, B.Sc. (Hons.): "The Spermatogenesis of Clibanarius padavensis and the Spermatogenesis of Lacotrephes griseus."

9. Mr. S. Narayanaswami, B.Sc. (Hons.): "Megasporogenesis and the origin of triploids in Saccharum."

10. Mr. K. G. Ananthanarayanan, B.Sc.: "Isolation of canavanine from Canavalia obtusifolia: A comparative study of Canavanase and Arginase: Nitrogen partition in the Urine of South Indians."

11. Mr. T. Venkataramana Reddi, B.Sc. (Ag.): "Genetic studies in the seedling colours of sorghum."

12. Mr. P. M. Sivaramakrishna Ayyar, B.Sc.: "Water Melon Urease."

DOCTOR OF SCIENCE.

1. Mr. K. Subbaramaiah, M.Sc.: "Investigations on the Liesegang Phenomenon: Scattering of light by colloidal systems."

2. Mr. P. Kotisvaram, B.Sc. (Hons.): "Molecular association as studied by Raman Effect."

3. Mr. K. S. Gururaja Doss, M.Sc.: "Kinetics of the formation of adsorption films of soluble substances at surfaces of aqueous solutions."

MASTER OF ORIENTAL LEARNING.

Mr. K. Venkatarama Sastri: "Absolutism of Vedanta according to Gaudapada."

CONFERENCES

The following teachers were deputed during 1939 to represent the University at the various Congresses or Conferences named : —

Indian Science Congress Session at Madras—in January 1940.
The Members of the Departments of Zoology, Biochemistry, Botany, Mathematics and Geography.

Indian Statistical Conference at Madras—in January 1940.
Dr. P. J. Thomas, Professor of Indian Economics.
Sri N. Sundararama Sastri, Lecturer in Statistics.

Indian Philosophical Congress at Hyderabad—in December 1939.
Sri S. S. Suryanarayana Sastri, Reader in Indian Philosophy.
Dr. C. Kunhan Raja, Reader in Sanskrit.

Indian Political Conference at Lahore—in January 1940.
Dr. E. Asirvatham, Reader in Politics and Public Administration.

Indian Economic Conference at Allahabad—in January 1940.
Dr. P. S. Lokanathan, Reader in Economics.

Indian History Congress at Calcutta—in December 1939.
Dr. N. Venkataramanayya, Reader in Indian History.
Sri V. R. Ramachandra Dikshitar, Lecturer in Indian History.

16th Session of the Indian Historical Records Commission at Calcutta.
Sri K. A. Nilakanta Sastri, Professor of Indian History and Archaeology.

11th Conference of the Indian Mathematical Society at Hyderabad —in December 1939.
Dr. R. Vaidyanathaswami, Reader in Mathematics.

LIST OF ACKNOWLEDGMENTS

DIPOLE MOMENTS IN CHEMISTRY*

The Sir Subramanya Ayyar Lectures for 1938-39.

BY

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INTRODUCTION.

In introducing a series of lectures such as these, it is proper for an author to express as warmly as possible his sense of gratitude for the honour done to him by the University of Madras, in inviting him to give them. I also take this opportunity of expressing my warmest thanks to the authorities of the University for providing me with an occasion to expound the progress and present state of knowledge in a branch of science in which I was working for the last few years.

The whole subject is of comparatively recent growth having been ushered only in 1912 by Prof. Debye. For the first one decade but little progress was made, as the idea of dipole moment remained largely in, what one may call, the domain of physics.

The importance of the concept, for an understanding of the structure of chemical molecules, was then realised by a number of physical chemists, prominent among them being Prof. C. P. Smyth of the Frick Chemical Laboratory of the Princeton University, and Jacques Errara, of the University of Brussels and a number of papers were published between 1925-1927. The subject soon developed with great rapidity, and many eminent organic chemists, like Prof. N. V. Sidgwick of Lincoln College, Oxford, Prof. E. Bergmann, formerly of the University of Berlin and now at The Daniel Sieff Research Institute, Rehovoth, Palestine, and Dr. C. J. W. Le Fevre, of University College, London, investigated the dipole moments of large numbers of organic molecules and thus a period of maximum activity was witnessed between 1932-1936. Alongside of this, progress was also kept up on the theoretical aspects of the sub-

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ject by mathematicians and physicists, like Prof. P. Debye, Prof. Lennard Jones, etc. Yet we are now in a stage of virtual impasse, where further advances in the application of dipole moment measurements to the elucidation of the structure of the more complex molecules, is beset with difficulties of a physico-mathematical nature. These difficulties are sure to be overcome in the near future. In this connection it is interesting to observe, that the development of other modern discoveries like X-rays, Electron diffraction, and Raman spectra, have more or less also followed similar stages of progress. But even with this speed of development in the applications of modern physical theories it is increasingly difficult to follow all the current scientific literature. As Prof. Donnan recently pointed out (1938), it will indeed take the full time resources of a Reader in Theoretical Chemistry in modern universities to keep abreast of all these developments and take part in some of them.

In preparing these lectures for publication, I have made no attempts to amplify any of the topics. My aim has been mainly to interest my fellow workers in other branches of Physics and Chemistry in the useful technic of dipole moment measurements. For fuller treatment and further details, the texts and the Journal articles given in the appendix must be consulted.

<div align="center">CHAPTER II.</div>

DIPOLE MOMENTS, THEIR MEASUREMENTS, AND SIGNIFICANCE.

INDUCED ELECTRIC MOMENT.

When matter is subjected to the action of an electric field, it gets polarised, and the amount of polarisation P is proportional to the applied field E, the proportionality constant called susceptibility being measured by $\dfrac{\varepsilon-1}{4\pi}$ where ε is the dielectric constant. Thus

$$P = x \cdot E, \qquad \text{and} \quad x = \frac{\varepsilon-1}{4\pi}.$$

But considered from the point of view that matter is made up of molecules, each of which acquires an average induced moment m, $P = n\,m$, where n is the number of molecules per cc. The moment m induced in each molecule is caused not only by

the applied field E, but in addition, by the resultant polarisation field F of the surrounding neighbours and thus

$$P = n[E + F]\gamma$$
$$= n[E + vP]\gamma$$

where γ is the "polarisability" of each molecule and v a proportionality constant connecting the polarisation P and the resultant inner field F in the medium. Under the idealised conditions of either a perfectly random distribution of the neighbouring molecules as in a gas, or a regular arrangement of the molecules into a cubic lattice pattern, the constant of the inner polarisation field v is $\dfrac{4\pi}{3}$. Hence

$$P = n\gamma \left(E + \frac{4\pi}{3}P \right) = x\text{E.}$$

Substituting for P and x, we get

$$\frac{\varepsilon - 1}{\varepsilon + 2} = \frac{4\pi}{3} n \cdot \gamma.$$

This is known as the Clausius-Mosotti equation and is the electrical analogue of the Lorenz-Lorentz equation for Molecular Refractivity. In fact the two expressions for Molecular Refractivity and Molecular Polarisation should be identical on Maxwell's theory, when for refractive index the value for long wave lengths is adopted.

PERMANENT ELECTRIC MOMENT.

It was however soon found that a large number of substances exhibited an additional electrical polarisation, the extra term frequently being very considerable. It was to account for this that Debye propounded in 1912, his famous concept of a permanent electrical moment, the idea being that in these cases the extra polarisation is due to a kind of marshalling or orientation of all the molecules in the direction of the applied electric field, in virtue of an inherent dipole character of the molecule. Such an orientation will be however disturbed by the thermal agitations, and Debye, by applying the theory already developed by Langevin for the analogous magnetic case, succeeded in deriving an expression for the equilibrium *orientation* polarisation at any temperature.

The actual degree of *orientation* polarisation P_o at any temperature will be lower than the maximum possible polarisation, $P_n = n\mu$, n being the number of molecules per c.c. and μ the perma-

nent moment, by a factor given by a function $L\left(\dfrac{\mu F}{kT}\right)$ known as the Lorenz function. Here k is the Boltzman constant and the function $L(x)$ is given by $L(x) = \text{Coth } x - \dfrac{1}{x}$ The value of this function for the normal conditions of $\mu F < kT$ is to a first approximation given by $\dfrac{x}{3}$. Thus

$$P_o = P_n L \left(\frac{\mu F}{kT} \right)$$

$$= n\mu \left(\frac{1}{3} \frac{\mu F}{kT} \right)$$

$$= n \cdot \frac{\mu^2}{3kT} \cdot F.$$

If now this value for the orientation *polarisability* $\dfrac{\mu^2}{3kT}$ is added to the original static polarisability γ, then for the conditions of perfectly random distribution and orientation of the neighbouring molecules, the Clausius-Mosotti equation is modified into

$$\frac{\varepsilon - 1}{\varepsilon + 2} = \frac{4\pi}{3} n \left(\gamma + \frac{\mu^2}{3kT} \right)$$

or in terms of a gram mole,

$$\frac{\varepsilon - 1}{\varepsilon + 2} \frac{M}{d} = \frac{4\pi}{3} N \left(\gamma + \frac{\mu^2}{3kT} \right)$$

where M is the molecular weight, d the density, and N the Avogadro number. This equation can be expressed in the form

$$\frac{\varepsilon - 1}{\varepsilon + 2} \frac{M}{d} = P = A + \frac{B}{T}$$

$$\text{where} \quad A = \frac{4\pi}{3} N\gamma$$

$$\text{and} \quad B = \frac{4\pi N}{9k} \cdot \mu^2$$

It is thus seen that P is an inverse function of the absolute temperature T.

In this derivation, only the potential energy of orienta-
tion of the dipoles is considered. The more rigorous calculation
by W. Alexandrow, (1921) taking into consideration the kinetic
energy as well, introduces no change in the final expression
as the μ is independant of kinetic energy of the molecule. It is
however interesting to learn from this calculation, that among
molecules with any orientation φ, only those dipoles with a kinetic
energy less than the potential energy contribute to the mean
moment. In other words, the P_0 is caused only by those molecules
which pendulate about E, and not by those which perform full rota-
tions. The same equation stands also verified by the newer
methods of quantum-mechanics, wherein the energy levels of the
molecules are considered as quantised. It must be pointed out
that in this case the final formula includes a small additional tempe-
rature-dependant term, which however assumes significance *only*
at very low temperatures, and that again only for molecules with
small moments of inertia such as HCl. The expression for the mean
moment m of a molecule, takes the form

$$m = \frac{\mu^2}{3kT} \left(1 - \frac{1}{3}\frac{T_k}{T} \right) E,$$

where T_k is a characteristic temperature for the molecule given by

$\dfrac{h^2}{8\pi^2 Ak}$ A being the moment of inertia. The value of T_k is only

15°K, even for the molecule HCl, and most polar substances
cannot be maintained in the ideal gaseous state for which alone
these equations are valid, long before such low temperatures are
reached. (Debye and Sack, 1934).

THE REALITY OF DIPOLES:

There are direct evidences for these permanent molecular di-
poles, originally postulated by Debye. What may be regarded as the
most striking of them all, is a rather pretty experiment conducted by
Eguchi in 1925, and verified 10 years later by Gemant at Oxford.
(A. Gemant, 1935). It consists in allowing molten wax admixed
with some polar substances such as esters, to slowly solidify in a
strong electric field, when permanently electrified bodies called
" Electrets " are formed. These are electrical analogues of the per-
manent magnets, and retain their charge, under suitable conditions,
even for one year. Although the explanation of this phenomenon
is not quite simple, the dipoles here are as it were frozen in an ori-
·ented direction. To be precise, the orientation of the molecules

leads to an oriented crystallisation, and this is further accompani-
ed by a secondary piezo-electric effect in the solidified hard wax. It
is this effect which gives rise to the steady charge.

As another interesting evidence, can be considered Mulliken's
experiments on the ionisation potential of the non-bonding elec-
trons attached to certain atoms in polar molecules, such as the iodine
atom in methyl iodide or the oxygen atom in water, aldehydes,
and ketones. (Mulliken, 1937). The ionisation potential in each
case is definitely lower than the value for a neutral atom, indicating
an accumulation of negative charge on or near the atom, and thus
the formation of an electric dipole. This lowering in potential is
also parallel to the observed magnitude of dipole moment.

The existence of a permanent dipole can also be proved from
its characteristic behaviour when placed in an inhomogene-
ous electric field. For, while in a homogeneous field the action on a
dipole will be only to orient it, in an inhomogeneous field, on account
of the unequal forces acting on the two oppositely charged poles,
there will be in addition either an attraction or a repulsion on the
molecule as a whole, depending on the favourable orientation of the
molecule. Therefore when a thin ribbon shaped beam of these mole-
cules is shot through an inhomogeneous field, the image received
on the plate is *broadened* out. If the beam is composed of non-
polar molecules alone, the applied electric field will induce mo-
ments in them all in the same direction, and there will be only a
unidirectional and small *displacement* of the beam. This small
displacement of the beam, caused by the *induced* moments is ne-
cessarily present also in the image of the beam of polar molecules.
The actual theory of the broadening is not however so simple as
pictured here, depending as it does upon the energies of transla-
tion and of rotation of the molecules. [Fraser: " Molecular
Rays" (1931) page 114.] This characteristic behaviour of di-
poles, has been developed as a means for determining the dipole
moment of free molecules, independant of any dielectric constant
measurements, but on account of the difficult technique involved
it has rarely been employed outside of Prof. Stern's Laboratories.
The method is also not capable of high accuracy, particularly for
molecules with small moments of order 1 to 2×10^{-18} e.s.u., it
being difficult to exactly determine the intensity distribution in
the broadened beam. This method has been however of great
utility in handling substances such as those with high m.p. $(200^\circ$
to $300^\circ C)$, which are not amenable to other methods of measure-
ment requiring solution in a non-polar solvent, or the maintenance

in a gaseous state. One of the striking results obtained by this method has been the definite value of $\sim 2 \cdot 0 \times 10^{-18}$ e.s.u. found for the moment of penta erythritol $C(CH_2OH)_4$, a moment which would be unexpected at first sight, on account of the apparent tetrahedral symmetry of the molecule. Among the other interesting results obtained by this method are the high values for the moments of the alkali halide molecules in the gaseous state, where they exist in a covalent condition [Rodebush, Murray, and Bixler, (1936)].

MEASUREMENTS OF DIPOLE MOMENTS.

(a) Measurements on gases.

The most elegant and convenient method for evaluating the dipole moments is through a determination of the dielectric constant and density, and thence the dielectric polarisation to which Debye's theoretical equation can be applied. Thus

$$P = \frac{\varepsilon - 1}{\varepsilon + 2} \cdot \frac{M}{d} = A + \frac{B}{T}$$

$$\text{where} \quad A = \frac{4\pi}{3} N\gamma, \quad \text{and} \quad B = \frac{4\pi N}{9k} \cdot \mu^2.$$

The dipole moment μ can be calculated from the value of B, which is obtained from P at any one temperature if we know A, or quite independently, from the values of P at two or more temperatures, as a slope of the straight line $P - 1/T$. The applicability of this equation is however limited to that state of matter which obeys the ideal gas laws, where the dipoles are free to orient themselves perfectly at random. Therefore, before applying Debye's equations to the measurements carried out even for the vapour state, adequate allowances must be made for the departures from the ideal gaseous condition. A large number of such measurements have been carried out by, among others, Zahn (1924, 1926, 1930), Smyth and McAlpine (1933, 1934), McAlpine and Smyth (1933), Groves and Sugden (1934), Kubo (1935), Watson (1927), Watson, Rao and Ramaswamy (1931, 1934).

The dielectric constant of the gas or vapour at a known pressure is measured in any suitably sensitive capacity measuring circuit, as a ratio of the capacity of the condenser filled with the gas to the capacity for vacuum. As the increase in capacity of the condenser on filling with the gas is only of the order of $\frac{1}{1000}$ of its original capacity, due corrections must be applied for the induct-

ances of the leads and other stray capacity effects [H. E. Waston, (1927)]. The polarisation of the gas, is given by

$$P = \frac{\varepsilon - 1}{\varepsilon + 2} \cdot \frac{M}{d}$$

$$= \frac{\varepsilon - 1}{3} \cdot V, \text{ since } \varepsilon \text{ is very nearly equal to 1,}$$

$$= \frac{\varepsilon - 1}{3} \cdot \frac{RT}{p}$$

where p is the pressure of the gas, which is assumed to obey the ideal gas laws. To get at the correct value of V, the observed value of pressure p must be corrected for the departures from the ideal state by using one of the appropriate equations of state. If Van der Waal's expression is adopted, the values of constants a and b can be taken from any standard tables such as Landolt-Bornstein. P is then given as

$$P = \frac{\varepsilon - 1}{3} \cdot \frac{RT}{p \left[1 + \frac{p}{RT} \left(\frac{a}{RT} - b \right) \right]}$$

The corrected value of P at any temperature can also be obtained by measuring the dielectric constants for *more than one* pressures, and extrapolating the experimental P values,

$$P = \frac{\varepsilon - 1}{3} \cdot \frac{RT}{p}$$

to zero pressure. For the low pressures at which the dielectric measurements are usually made, it can easily be shown that the polarisation-pressure curve is practically a straight line, the slope of which is proportional to the second virial coefficient of the gas. Extrapolation to zero pressure is therefore a simple matter.

(b) *Measurements on solutions.*

As it happens, a great majority of organic substances are not sufficiently volatile even at higher temperatures without decomposition. On the other hand Debye's equation cannot be applied to the condensed state of polar molecules and in fact the equation noticeably fails in these cases. Frequently the polarisation calculated from the Debye expression using the moment value found for the gaseous state is considerably more than the polarisation calculated according to the Clausius-Mosotti expression $\dfrac{\varepsilon - 1}{\varepsilon + 2} \cdot \dfrac{M}{d}$

from the dielectric constant ε, and density d of the liquid. Indeed, in some cases in order to satisfy the Debye expression, ε will have to take meaningless negative values.

This difficulty in directly applying Debye's theory to the condensed state of polar molecules, has been got over by the familar physico-chemical device of dissolving the polar molecules in a nonpolar solvent medium, measuring the polarisation of the solution for various concentrations, and then extrapolating the values to the condition of "infinite dilution", where the polar solute molecules will be ideally separated. This is the most handy and widely adopted method of determining the moment of a great majority of organic molecules.

The dielectric constant of the carefully prepared solutions is measured, as the ratio of the capacity of a condenser filled with the liquid, to the empty capacity of the same. The sources of error and precautions to be taken, are described in the literature (Rau and Swamy, 1934[1]). A concentric metal tube condenser of the type shown in Fig. 1. has been found to be of great con-
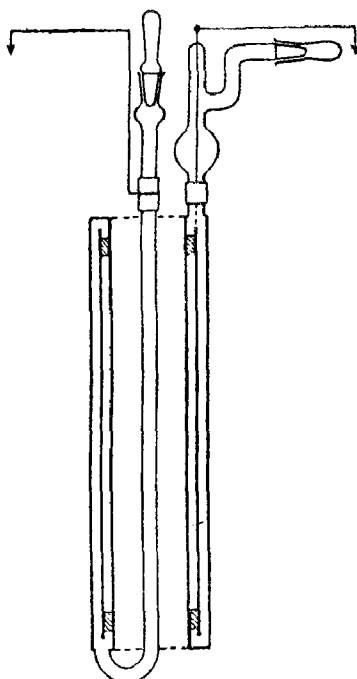
Fig. 1.

venience, particularly for accurate temperature coefficient measurements without employing any elaborate thermostatic controls. For the corresponding determinations of densities and their tempe-

2

rature coefficients a dilatometer shown in Fig. 2. is very suitable and also easily made in the laboratory.

The dielectric capacities of the condenser can be measured by one of several methods. The method of measurement, employing the well known " bridge " circuit, is capable of very high ac-
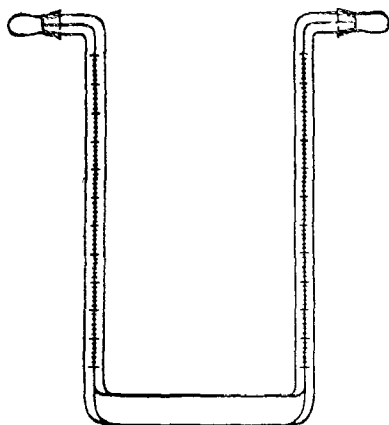
Fig. 2.

curacy, and has the following additional advantages : (i) provides a measure and hence control over the power factor of the solutions (ii) since comparatively low frequencies can be used for measurement, the troublesome errors caused by the inductance of the leads are avoided. Fig. 3. gives the diagram of a bridge circuit. A more convenient method however is what is known as the "heterodyne method," in which an oscillating circuit, with and without the liquid condenser in parallel, is set to exact resonance with a standard circuit, each time by tuning the beat note produced against a fixed audible frequency. With a frequency of oscillation of the measuring circuit at 10^6 cycles per second, a change of 1 beat per second can be easily detected, and thus the method is virtually capable of an accuracy of setting of the standard condenser employed to measure the capacity, to 1 part in a million. Fig. 4. gives the diagram for a " heterodyne apparatus " (Rau, 1936).

From the polarisation of the solution $P_{1.2}$ thus determined through the dielectric constant and density measurements, it is easy to calculate the polarisation P_2 due to the polar solute alone, assuming the mixture law to hold.

$$P_{1.2} = f_1 P_1 + f_2 P_2$$

where P_1 is polarisation of solvent and f_1 its molar concentration, and P_2 is polarisation of solute and f_2 its molar concentration.
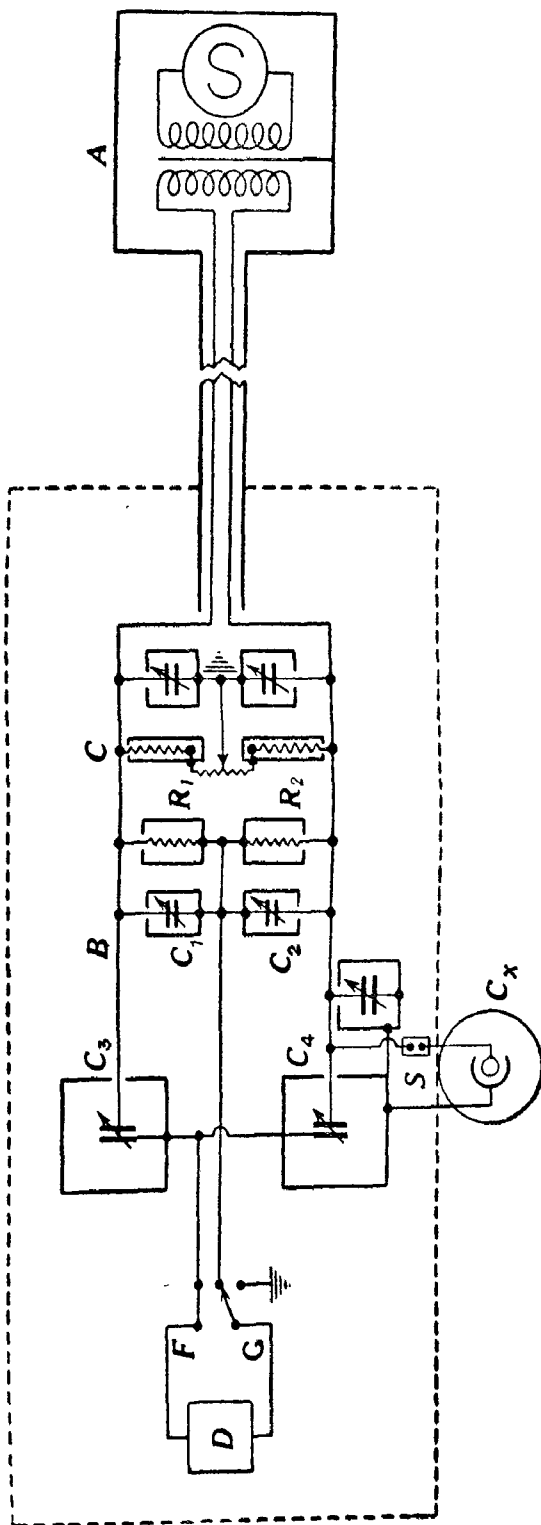
Fig. 3.
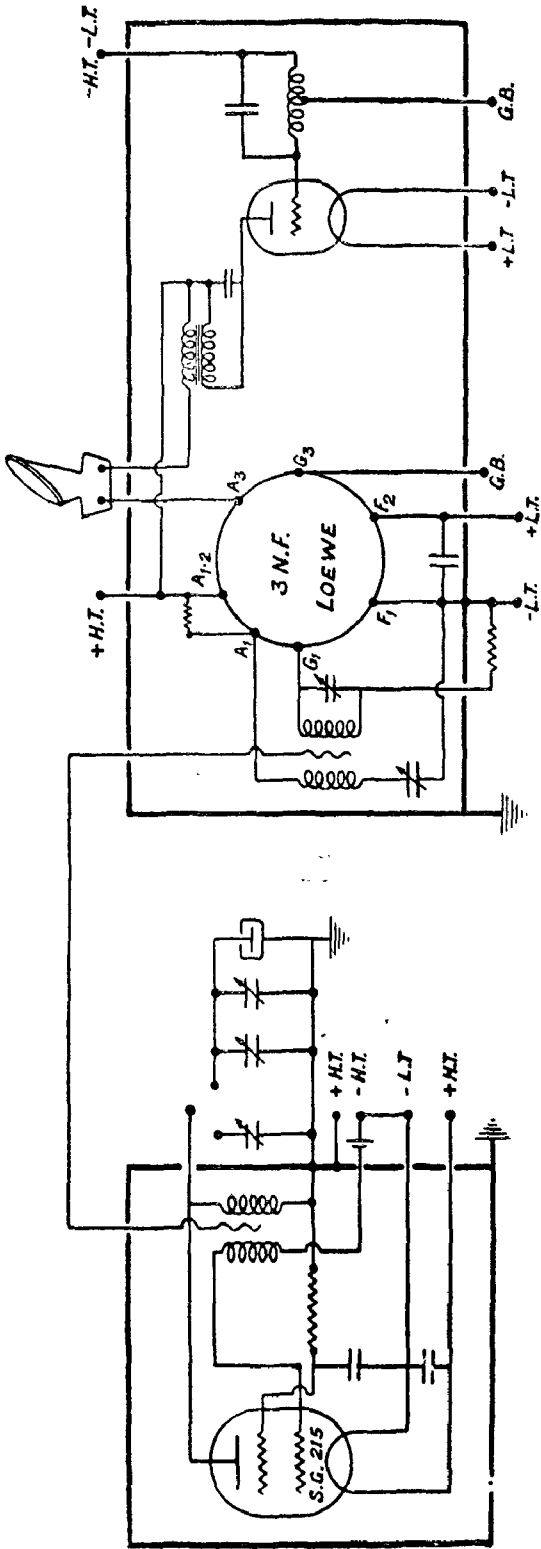
Fig. 4.

Then the calculated values of P_2 can be extrapolated to the limit $f_2 \to 0$, either graphically or otherwise.   It can be shown that such a method of computation is wasteful of a great deal of the accuracies reached in the experimental values and the value of $P_{2\infty}$ thus obtained is greatly in error.   This is chiefly because, in the process of calculating P_2 the significant quantity $P_{1\cdot2} - P_1$ gets divided the small fraction f_2 ($\sim 0\cdot01$), and thus all errors in $P_{1\cdot2} - P_1$ are grossly exaggerated.   The ideal and correct method to employ is the analytical one suggested by Hedestrand (1929), and emphasised by Rau in 1933.   This method is however still not as universally adopted as it should be.   In one instance, a simple recalculation of the results according to this method was successful   (Rau, 1933)   in   effectively   closing   a   controversy that had developed between Donle (1933) and Williams (1933) over their respective moment determinations for p-chloro—phenol, $viz.$, ($2\cdot22$ and $2\cdot68 \times 10^{-18}$ e.s.u.). These differing values were not due to any experimental inaccuracies or other spurious effects of association as contended, but only to the differing methods of extrapolation to $P_{2\infty}$.   The values recalculated by Hedestrand's method, using the respective author's own experimental data, were $2\cdot22$ and $2\cdot33 \times 10^{-18}$ and thus almost identical.   It might be that, the irregular   results   for P_2 at $very$ dilute   solutions,   reported   by Hoecker (1934) Svirbely, Ablard and Warner (1935), are also due to a few systematic errors, which have been made prominent during the division by the very small values of f_2.

The principle of Hedestrand's method is to plot the dielectric constant and density values against concentration c_2 and from the slopes α and β of the quite linear graphs, derive $P_{2\infty}$ for the limit $f_2 \to 0$, according to the equation

$$P_{2\infty} = \frac{\varepsilon_1 - 1}{\varepsilon_1 + 2} \frac{1}{d_1} \left(M_2 - \frac{M_1}{d_1} \beta \right) + \frac{3M_1}{(\varepsilon_1 + 2)^2 d_1} \alpha$$

$$= A'(M_2 - B'\beta) + C'\alpha,$$

$$\text{where } \alpha = \frac{\delta\varepsilon_{1\cdot2}}{\delta c_2} \quad \text{and} \quad \beta = \frac{\delta d_{1\cdot2}}{\delta c_2}$$

Table 1 shows how the experimental data can be neatly arranged and the moment evaluated.   For the calculation of moment from the polarisation $P_{2\infty}$ the total induced polarisation term A in De-

bye's equation is required. This is taken usually as either the molar refractivity for the sodium D line MR_D , or the value $1 \cdot 15 \, MR_\infty$ where MR_∞ is the extrapolated value of molar refractivity for infinite wave length.

TABLE I *Coumarin*

Concentration of solute in mol fraction	10°C.		20°C		30°C		40°C.	
	E	d	E	d	E	d	E	d
0	2·299	0·8881	2·279	0·8774	2·260	0·8667	2·241	0·8560
0·00599	2·490	0·8909	2·462	0·8803	2·434	0·8697	2·406	0·8591
0·00918	2·590	0·8926	2·558	0·8821	2·525	0·8715	2·493	0·8609
0·01440	2·757	0·8949	2·716	0·8845	2·676	0·8740	2·635	0·8635
0·01748	2·856	0·8967	2·811	0·8861	2·766	0·8755	2·721	0·8650

	α	β	$P_2\infty$	$\mu \times 10^{18}$
10°	31·86	0·482	489·7	4·50
20°	30·36	0·488	477·6	4·51
30°	28·97	0·504	465·7	4·52
40°	27·45	0·514	451·4	4·52

$$(P_E = 48 \cdot 5)$$

EFFECT OF SOLVENT IN DIPOLE MOMENT MEASUREMENTS.

When measurements are pushed to such high accuracies it is soon found that the non-polar solvent molecules filling up the inter-dipolar space in the solutions are not without a specific effect on the moment value calculated for the solute molecule. This solvent effect, was vaguely anticipated, but definitely established for the first time by systematic work on the moments of nitro-benzene and chloro-benzene in various solvents, by Prof. H. Muller of Leipzig (1933).

One can picture the origin of this effect from simple considerations. It is known that most of the molecules carrying dipoles are non-spherical in shape, and can be represented on the average by ellipsoids of revolution about the dipole axis. If we consider a

dipole molecule such as in fig. 5 (Type I), surrounded by the polarisable solvent molecules, temporary dipoles will be induced in the latter of direction and magnitude (size of arrow) as indicated.
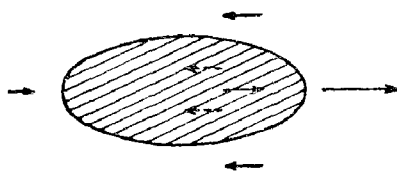
Type I.
Fig. 5.

The net effect of these induced moments, equivalent in all to four on the broadside and two on the end-on positions, is in the *opposite* direction to the original moment. It will be obvious that as this is necessarily associated with and superposed on the moment of the solute dipole, the moment measured in the solvent is less than that for the free molecule. On the other hand, for a molecule of shape Type II, Fig. 6, with the dipole at right angles to the major axis, the resultant of the induced moments is *positive* and thus such molecules show an enhanced total moment in solution. These two types
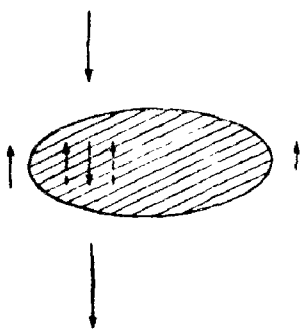
Type II.
Fig. 6.

of molecules are otherwise also characterised by a positive and a negative electro-optical Kerr constant, and therefore one can predict in advance the nature of the solvent effect. Prof. Weigle of Geneva (1933) was the first to submit these effects to a quantitative calculation, by assuming for the shape of a molecule, as a working hypothesis, a cone with a spherical cap at the apex, the dipole being situated in this cap. Higasi, in 1935 (see also 1934, 1936) generalised these calculations by taking the shape of the molecule as an ellipsoid of revolution. Independently of Higasi, Frank (1935) also extended the ideas of Weigle with a more rigorous calculation. The final equations show variations due to the different degrees of

approximations used in the calculations, but they are principally the same, and based on the fundamental equations for the values of the electric field sorrounding a dipole. Thus if m_x and m_y are the axial components of the dipole m, then the field strengths E_x and E_y at any point are given by

$$E_x = m_x \frac{(3\cos^2\theta - 1)}{\varepsilon r^3} + 3m_y \frac{(\sin\theta\cos\theta)}{\varepsilon r^3}$$

$$E_y = 3m_x \frac{(\sin\theta\cos\theta)}{\varepsilon r^3} + m_y \frac{(3\sin^2\theta - 1)}{\varepsilon r^3} \text{ where } \theta$$

and r are the polar co-ordinates.

Thence, the moments m_i induced at this point are

$$m_{ix} = E_x \cdot \alpha$$
$$m_{iy} = E_y \cdot \alpha,$$

where α is the polarisability. In the case of the simpler molecules, with moment along the x-axis only, and shape symmetrical about the same, the induced moments m_{iy} cancel out, and one has to take into consideration only the induced moments m_{ix} given by

$$m_{ix} = \frac{m_x(3\cos^2\theta - 1)}{\varepsilon r^3} \cdot \alpha.$$

The sign of this expression is positive or negative according as θ is less than $55°$ or more than $55°$. Thus, all the induced moments in the solvent molecules on and near the "end on" positions but within a cone of semi-angle $55°$ about the dipole axis, will contribute an *addition* to the solute moment, and the rest of the solvent molecules on and near the "broad side" positions will contribute a *reduction* to the solute moment. If the solute moleclue has a spherical symmetry with the dipole in its centre, the resultant of the induced moments in the surrounding solvent space will be zero. But with a solute molecule of shape Type I, Fig. 5, some of the solvent molecules in the " positive induced moment space " will be displaced by the *body* of the dipole molecule, and the net induced moment in the solvent is negative. Conversely with the solute molecule of Type II Fig. 6 some solvent molecules in the " negative induced moment space " will be displaced by the body of the dipole molecule, and the net induced moment is positive. The several expressions derived for the net induced moment are collected on page 19.

Before these solvent effects were traced out and definitely established, Raman and Krishnan (1927, 1928) had developed an equation for the polarisation of a condensed medium, in which such sub-

sidiary induced moments were postulated and taken into conside-
ration. The theory was developed primarily in order to account
for the decreased values of anisotropy for the molecules when
calculated from depolarisation data for light scattered in the
liquid state. [It can readily be seen from figures 5 and 6, that the
nature of the induced moments in both cases is to make the solute
molecule exhibit a lower anisotropy of polarisability, than the
real.] The negative and positive induced moments in the neigh-
bours as depicted above, also have the effect of altering the nature
of the "polarisation field" acting on the molecule under considera-
tion, into an anisotropic field. Hence the constant γ of the inner
polarisation field is no more equal to $\dfrac{4\pi}{3}$ in all directions as assum-
ed in Lorentz's theory, but is different along the three representa-
tive axes x, y, z, the deviations from $\dfrac{4\pi}{3}$ being taken as s_x, s_y, and s_z
respectively. In general, if the components of the moment along
the three axis are μ_x, μ_y, and μ_z, then,

$$\frac{\varepsilon-1}{\varepsilon+2}\frac{M}{d} = \frac{4\pi}{3}N\left[\Sigma\frac{a_x}{3}+\frac{\mu^2}{3kT}\right]+\frac{\varepsilon-1}{\varepsilon+2}N\left[\psi+\frac{\theta}{3KT}\right]$$

$$\text{where } \psi = \frac{1}{3}\Sigma a_x s_x$$

$$\text{and } \theta = \Sigma \overset{2}{\mu_x} s_x + 2\Sigma \mu_x \mu_y q_{xy}$$

where q_{xy} q_{yz}, q_{zx} are certain cross-terms involving the inner field
constants, and a_x, a_y, a_z are the optical polarisabilities along the
three axes.

This equation however presents a difficulty in its general appli-
cation since, correct values for s_x, s_y, s_z, i.e., the magnitudes of devi-
ations from the uniform Lorentz field have to be determined. No
method of directly computing them has yet been given but their
values can be deduced, in favourable cases, from the data on light
scattering etc. (Krishnan 1929, Krishnan and Row 1929). By this
means Raman and Krishnan and others have succeeded in show-
ing the general validity of the theory, and its applicability to other
properties of the liquid state, such as refractive and elec-
tric polarisation, and electric double refraction. (Raman and
Krishnan, 1927).

. This equation can be extended to the case of the polarisation of
a mixture of any two liquids. (Subbaramaiya 1934). If one of

3

the components of the liquid mixture is a *non-polar* solvent, then an expression can be deduced, for the true polarisation of the *polar* component only, and then extended, following the method of Hedestrand (Rau, 1935) to the limiting case of infinite dilution in the non-polar solvent. The final expression so obtained is

$$P_{2,\text{ ideal gas}} = P_{2\infty} - \left[N\psi_1 \frac{3\alpha\varepsilon_1}{(\varepsilon_1 + 2)^2} + \frac{\varepsilon_1 - 1}{(\varepsilon_1 + 2)^2} N\psi_2 + \frac{\varepsilon_1 - 1}{\varepsilon_1 + 2} \frac{N\theta}{3K} \frac{1}{T} \right]$$

In this equation, the quantity ψ_1, refers to the pure solvent, but ψ_2 and θ are those applicable to the solute molecules *in a state of infinite dilution in the solvent,* and not those for the pure homogeneous solute. Of the correction terms in the square bracket, the first two are generally small and negative, but the third which is the most significant can be negative or positive according as the solute molecule belongs to type I or type II. Table 2 shows how the new values of P_2 for nitrobenzene in benzene are sensibly constant in the different solvents, and equal to the vapour phase value as determined by Groves and Sugden. (1934).

TABLE 2.

Solvent	$t °C.$	$P_{2\infty}$	$N\psi_1 \dfrac{3\alpha\varepsilon_1}{(\varepsilon_1+2)^2}$	$N\psi_2 \dfrac{\varepsilon_1-1}{\varepsilon_1+2}$	$\dfrac{\varepsilon_1-1}{\varepsilon_1+2} \cdot \dfrac{N\theta}{3kT}$	P_2 10°	P_2 40°
Heptane ..	10	400·7	6·0	1·0	23·8	431·5	
	40	366·6	5·3	0·9	20·8		393·6
Cyclohexane ..	10	395·1	3·4	1·1	25·9	425·5	
	40	366·1	3·1	1·0	22·6		392·8
Carbon tetra-chloride ..	10	386·1	—	1·2	29·7	417·0	
	40	353·8	—	1·2	26·0		381·0
Benzene ..	10	378·1	13·5	1·3	30·5	423·4	
	40	349·7	12·0	1·2	26·7		389·6
Dioxane ..	10	366·8	4·0	1·3	31·3	403·4	
	40	341·9	3·6	1·2	27·3		374·0
Vapour value calculated from data of Groves and Sugden						426·2	389·0

Constants used in the above calculations.

	s_x	s_y	s_z	$\times 10^{25}$		
				a_x	a_y	a_z
Heptane ..	−2·09	1·0	1·0	185	132	132
Cyclohexane ..	−0·75	−0·75	1·5	131	131	98
Carbon tetrachloride.	0	0	0			
Benzene ..	−1·21	−1·21	2·42	141	141	71
Nitro-benzene ..	−1·21	−1·21	2·42	170	170	85

This equation has latterly been verified by Cowley and Partington (1936, 1937), for the case of more substances in different solvents, and found to be of general applicability. Also it bears, compared with the other quantitative expressions, the closest analogy to a very successful empirical equation deduced by Sugden (1934) from a study of a large number of experimental data on polarisation measurements. Sugden's equation is thus provided with a theoretical basis. Several other empirical equations besides the first one given by Muller (1933), have been put forward from time to time to take into account the change caused in polarisation value by the dielectric constant of the solvent. It can be shown (Rau, 1935, p. 508), that all these equations are related to Sugden's empirical equation and therefore to the Raman-Krishnan theory. A list of the several equations, both theoretical and empirical, is given below.

Theoretical Equations.

Weigle.

$$\triangle\mu = \frac{A\mu^3 n (\alpha_1 - \alpha_2)^2}{kT} + B\mu n \frac{(\alpha_1 + 2\alpha_2)}{3}$$

where A and B are factors depending upon the geometry of the solute molecule and α_1, α_2 are the polarisabilities of the anisotropic solvent molecule. The first term is of the order of $\frac{\mu}{100}$ only and hence negligible. B can be positive or negative, and as Glasstone has shown (1937, p. 121), the equation can be recast as

$$\triangle\mu = \alpha + C\mu \frac{\varepsilon - 1}{\varepsilon + 2}$$

where ε is the dielectric constant of the solvent, and α a small factor.

Frank.

$$\triangle\mu = A\mu\frac{\varepsilon - 1}{\varepsilon}$$

where A is a quantity whose magnitude and sign are determined by the shape of the molecule and the position of the dipole within it; A is evaluated by a method of graphical integration.

Higasi.

$$\triangle\mu = A\mu\frac{\varepsilon - 1}{\varepsilon}$$

where A stands for different expressions for different molecular shapes; thus for type I molecule

$$A = \frac{-1}{k^2 - 1}\left\{ 1 - \frac{k}{\sqrt{k^2 - 1}}\log\left(k + \sqrt{k^2 - 1}\right) \right\} - \frac{1}{3}$$

where k is the ratio of the two radii for the ellipsoidal molecule.

Rau.

$$[\triangle\mu]^2 \sim \triangle P = A + B\frac{\varepsilon - 1}{\varepsilon + 2},$$

$$\text{where} \quad A = N\psi_1\frac{3\alpha\varepsilon}{(\varepsilon + 2)^2} + \frac{\varepsilon - 1}{\varepsilon + 2}N\psi_2,$$

$$\text{and} \quad B = \frac{N\theta}{3kT}, \text{ sign of } \theta \text{ depending upon shape}$$

of the molecule as explained on page 16.

EMPIRICAL EQUATIONS.

Sugden.

$$\triangle P = \alpha - P_o\frac{\varepsilon - 1}{\varepsilon + 2}$$

where α is a small constant and P_o is the true orientation polarisation.

Müller.

$$\triangle P = - kP_o(\varepsilon - 1)^2, \quad \text{where} \quad k = 0 \cdot 075 \pm 0 \cdot 005.$$

Jenkins.

$$\triangle P = - C \frac{\varepsilon - 1}{\varepsilon}$$

obtained by recasting the original equation

$$P_l = A + \frac{C}{\varepsilon} \qquad \text{(See Rau 1935 p. 509)}.$$

The close relation between Sugden's formula and the expressions of Weigle and of Rau, is brought out in the above list of formulae. It would therefore appear that Weigle's calculations could provide a basis for computing independently from molecular constants the ψ and θ expressions occuring in the Raman-Krishnan theory. A necessity for extending Weigle's calculations was pointed out (Rau, 1935, p. 503) before Frank and Higasi published their papers. These authors have still neglected the first expression in Weigle's equation, and also the anisotropy of the solvent molecules, both of which appear in Rau's formula.

The theory of Raman and Krishnan, which has been successful in accounting for the solvent effect in dipole moment measurements, was previously used in order to adopt the expression for the polarisation in the gaseous state to the polarisation for the liquid state. The whole problem is thus intimately associated with the nature of the liquid state. Recently Debye, (1935, 1936) has endeavoured to take into account the concept of a quasi-crystalline nature of the liquid state, and thereby to derive a modified expression for the polarisation. On this theory, a free Debye orientation of the dipole is hindered on account of its coupling with a slowly changing quasi-crystalline field in the liquid medium around it such that

$$P_{o_{\text{liq}}} = P_{o_{\text{gas}}} \cdot R(Y), \text{ where } R(Y) = 1 - L^2(Y)$$

with $Y = \dfrac{E}{kT}$, E being the rotational coupling energy. Debye and his pupils (Debye and Ramm, 1937, Friedrick 1937), have estimated this 'rotation hindering energy" for some polar liquids from data on molecular polarisation, Kerr constant etc., and have found a good although only a qualitative agreement. There is however, as yet, no successful method for directly computing this value of E from molecular data. From an empirical study of the value of E found for different concentrations, Müller (1937) has recently extended

this Debye's new equation to solutions, and arrived at an expression of the form

$$P_2 = P_{2_{gas}} + \alpha + P_{o_{gas}} \frac{E_0\beta}{9k^2T^2} \frac{\varepsilon - 1}{\varepsilon + 2}$$

It is interesting to observe that this is again closely analogous to Rau's expression based on Raman-Krishnan theory, and to Sugden's empirical equation.

This is a major solvent effect. Some finer solvent effects have also been found which become significant only when non-polar molecules containing neutralised dipoles are measured. According to Frank and Sutton (1937), there are two such effects, one of the nature of induced polarisation caused by the electrostriction-like movements of the solvent molecules around each dipole, ("solvation polarisation") and the other a still smaller "Jenkins-Bauer effect" due to the fluctuation of the solvent effect around each dipole on account of the density fluctuations in the medium.

DIPOLE-DIPOLE AND ION-DIPOLE INTERACTIONS.

We will next pass over rapidly some analogous inter-molecular coupling effects in which two dipole fields take part. When two dipoles are not sufficiently separated as when they are present in a concentrated solution, there is a coupling force between them which in general hinders their mutual freedom of orientation. If the molecules are sufficiently close together, they interact strongly enough to form regular association complexes with either zero, or double the moment of each molecule, according to which of the two types of molecular shape they have. (Fig. 7.)

(a) $\mu = 0$ (b) $\mu = 2m$
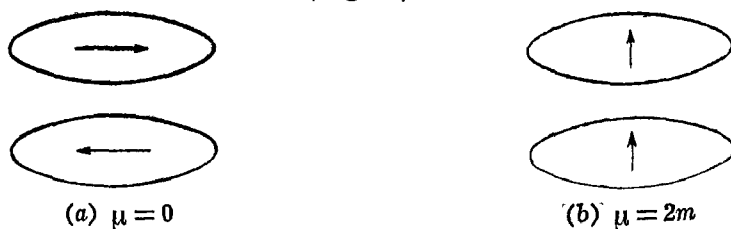
Fig. 7.

When there is the 'a' type of association, P_2 obviously decreases with increase in concentration. In the other case 'b', P_2 shows a rise with concentration. Frequently, as with alcohols, a maximum, or a minimum followed by a maximum are observed. Wolf and others, Wolf and Herold (1934), Sakurada (1934), have explained the course of these polarisation concentration curves by postulating the existence of various association complexes such as di—, tri—, etc.,

molecules. Such calculations appear to be a little artificial [Hertel and Dumont (1935) Kumler (1935), Martin (1937).] Thus, by assuming a bimolecular association of type 'a' only the degree of association can be calculated as $\dfrac{P_\infty - P_{c_2}}{P_\infty} = \alpha.$ In the case of a number of substances this factor α runs parallel and almost identical with the α calculated from freezing point determinations. But a closer inspection shows that any inference regarding the actual formation of a bimolecular complex is not necessarily correct. For instance, in the case of nitro benzene, when the "association constant" $k = \dfrac{(C_6H_5NO_2)_2}{(C_6H_5NO_2)^2}$ is calculated, it is found to rapidly change: [Davy and Sidgwick (1933)]. Table 3.

TABLE 3

C moles per litre	α by		k by	
	Freezing point.	Molecular Polarisation.	Freezing point.	Molecular Polarisation.
0·1	·049	·045	·271	·247
0·5	·217	·186	·334	·281
1·0	·356	·313	·429	·332
1·5	·470	·396	·557	·362
2·0	·570	·460	·771	·394

The decrease in P_2 in such cases is really due to the mutual interaction of the dipoles rather than to any chemical combination or co-ordination. Van Arkel and Snoek (1934) have been successful in empirically modifying the Debye expression for polarisation, by introducing into it a term for this interaction energy of the form

$$\frac{\mu^2}{r^3} = n \cdot \mu^2.$$

Van Arkel's expression for orientation polarisation is

$$P_0 = \frac{4\pi}{2} N \frac{\mu^2}{3kT + cN\mu^2}$$

where c is a constant.

This equation is closely obeyed in a number of cases, and there is therefore no real association. Where this is not obeyed, it can be then accounted for as due to real association. Van Arkel's empirical equation obtains a theoretical basis in the recent theory of "Hindered Rotation" put forward by Debye. It is only on the basis of this correlation, that Müller has been able to apply Debye's new theory to solutions. It may be remarked that this explanation for the course of molecular polarisation with concentration in solutions, is analogous to the explanation offered by the well known Debye-Huckel-Onsager theory for the decrease in conductivity by the retardation forces created by "ion-atmospheres."

When there are *free* ions in a dipole medium, the field immediately round the ions is inhomogeneous, and of the order of 10^7 to 10^8 Volt per cm. The solvent dipoles are then oriented and *attracted* to the ions where they are immobilised into a "solvation layer" round each ion. Fig. 8. As a consequence, the dielectric constant of the
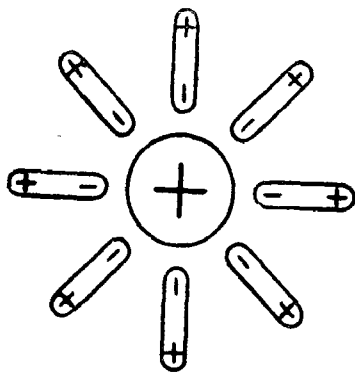
Fig. 8.

polar medium such as water containing ions in solution *decreases,* (Blüh 1924, 1935 Gore and Briscoe 1936) the decrease being proportional to the concentration of the ions and to the degree of hydration. With further rise in concentration however, there is a rise in dielectric constant. This rise in dielectric constant is due to quite a different effect and is explained on the Debye-Falkenhagen theory, as caused by an electrical dissymmetry produced in the ionic-cloud round a moving ion, on account of the "relaxation" forces. The increase in dielectric constant is proportional to the square root of the concentration. [Debye and Falkenhagen (1928) M. Jezewski (1936).]

CHAPTER III.

RELATION BETWEEN DIPOLE MOMENT AND THE STRUCTURE OF MOLECULES

DIPOLES FORMED BY THE SEPARATION OF UNIT CHARGES

In the last chapter we have dealt with the physical significance and the effects of the net electric moments existing in polar molecules, without going into the exact origin and the order of magnitude of these moments. The order of magnitude of moment in simple molecules can be easily computed, as

$$\mu = e \times r = 4 \cdot 77 \cdot 10^{-10} \times 10^{-18} \text{e.s.u.}, \text{ i.e., } 5 \times 10^{-18} \text{e.s.u.},$$

if in the formation of the dipole one complete unit of charge e has been shifted over from one atom to its neighbour, the inter-atomic distance r being of the order of I A° unit. Under favourable circumstances, this leads to an ionic dissociation of the molecule, but there are a number of cases where the chemical link remains intact, such as in what are known as 'coordinate' or 'semipolar' links. In all cases, where such links are present in a molecule, the moments are high, and of the order of $4-6 \times 10^{-18}$ e.s.u. A simple example of a molecule with a semi-polar link in it, is to be seen in nitro-benzene.
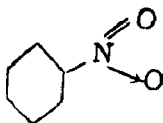
with a moment of $4 \cdot 0 \times 10^{-18}$ e.s.u. Several instances where the unit charges are separated over considerable distances, are provided in the amphoteric or "zwitter" ions, which occur in aqueous solutions of amino-acids and other amphoteric electrolytes, like sulphanilic acid (i), Methyl orange, (ii) and glycyl gylcine (iii).
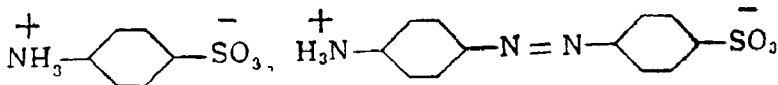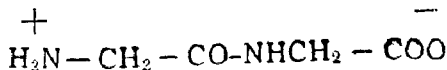
It is difficult to determine the exact dipole moments of these ions but Wyman (1933) (1934), has deduced from certain assumptions the moment of amino butyric acid as 22×10^{-18}. One can at present go only as far as measuring the coefficient of increase in the dielectric constant of an aqueous solution of these acids, a quantity which has been found to be linearly related to the dipole moment. On this basis, it is found that the polypeptides starting from glycyl glycine up to heptapeptide show a linear increase of moment with the number of glycine units, indicating thereby that the peptide chains are linear, at least up to hepta-peptide stage. [Devoto (1934), Halbedel (1936).]

ELECTRIC MOMENT ARISING IN CHEMICAL OR COVALENT BONDS.

It is not necessary that there be a complete separation of unit charges, in order to form a dipole. In all molecules, each chemical ie., covalent or non-ionic bond, can also be the seat of a significant dipole moment. For, an unequal sharing of the bonding electron pair between the neighbouring atoms, will give rise to an electrical dissymmetry in the bond and therefore to a dipole moment. Such "bond moments" are usually of a lower order of magnitude and have values between 0 and $2 \cdot 0 \times 10^{-18}$ e.s.u. In special cases, such as when multiple links are present, the bond moment can increase up to 3 or 4×10^{-18}. When the two chemically linked atoms are identical, and occupy symmetrical positions in the molecule, there is always an equal sharing of the electrons, and therefore the electric moment in this bond is zero. Whereas, in a hetero-atomic link, such as C-Cl, the atom with the greater positive nuclear charge viz. Cl, will attract and hold the bonding electron pair for a greater time, and thus an electrical dissymmetry will be produced in the bond. The sign of the resulting moment can be most conveniently expressed as $+\rightarrow$, the arrow pointing in the direction of flow of the electronic charge. In the majority of cases therefore, the negative end of the moment tends to be towards the atom with the greater nuclear charge, ie., towards the atom which has the higher atomic weight. It has not been possible hitherto to theoretically compute the magnitude of the moment for any bond A-B. Mulliken (1935) has formulated an expression of the form.

$$\mu_{AB} = Q_B r - 4ezabs + \mu_s$$

where $Q_B \ (= -Q_A)$ is the net charge in atom B, r the distance between the centres of A and B, e the electronic charge, and the other

quantities are connected with the wave mechanics of the system. In the present state of our knowledge this formula is not of much use in any effective computations, but it can explain or predict differences in moment between those bonds for which the first term can be calculated and the others estimated. Thus C. P. Symth (1937) has, with the help of this formula, countered the contention of Fuchs and Wolf (1935) and of Trieschmann (1936), that the moment in the C-H bonds is abnormal and has its negative end towards the H atom. The actual value of any bond moment is determined but to a variable extent by the electrical conditions in its environment. It is however possible, as will be shown later, to deduce the magnitudes of the moments in the various inter atomic bonds, from a systematic study of the moments of a large number of molecules. When the different atoms are arranged in the increasing order of moments for their binding with a common atom, say H, they fall into a scale closely analogous to "the electro-negativity" scale established by Pauling (1932) on the basis of excess bond energies, and to the scale established by Mulliken (1934) based on electro-affinities.   (See also, Malone 1933, Malone and Ferguson 1934).

This coincidence apparently gives support to the conception that all truly covalent bonds are non-polar, but have superposed on them a partial ionic character, based on the difference in the " electro-negativity" of the atoms.

Table 4 gives the bond moments, as recently recalculated by C. P. Smyth, (1937; 1938).

It will be noticed that the moments of double and triple bonds are more than two and three times the values for the single bonds. Semipolar bonds have polarities intermediate between those of ordinary covalent bonds and those of electrovalent-bonds.

TABLE 4.

Bond.	Moment $\times 10^{18}$	Bond.	Moment $\times 10^{18}$	Bond.	Moment $\times 10^{18}$
H–As	0·10	C–C	0	N–O	(0·3)
H–P	0·36	C=C	0	N=O	2·0
H–I	0·38	C≡C	0	N→O	3·3
H–S	0·68	H–C	0·3	P–I	0
H–Br	0·70	C–I	1·29	P–Br	0·36
H–Cl	1·03	C–Br	1·48	P–Cl	0·81
H–N	1·31	C–Cl	1·56	As–I	0·78
H–O	1·51	C–F	1·51	As–Br	1·27
P→O	2·4	C–O	0·86	As–I	1·64
P→S	2·4	C=O	2·5	As–F	2·03
Cl–O	0·7	C – S	1·0	Sb–I	0· 8
Cl→O	2·3	C=S	2·8	Sb–Br	1·9
I–Br	0·4	C–N	0·45	Sb–Cl	2·6
I–Cl	0·8	C=N	0·9	$\overset{+}{K}$–$\overset{-}{Cl}$	6·3
S→O	3·0	C≡N	3·6	$\overset{+}{Na}$–$\overset{-}{I}$	4·9

THE RESULTANT ELECTRIC MOMENT OF MOLECULES

(a) *Zero dipole moment.*

It was one of the earliest facts to be realised that the effective moment of the whole molecule is a vectorial sum of the bond moments, and not an additive quantity, so that in a completely symmetrical molecule with a centre of symmetry, whatever may be the bond moments, the moment of the molecule as a whole is zero. Thus CCl_4 with four C-Cl bonds has zero moment, while $CHCl_3$ and CH_3Cl with three C — Cl and one C — Cl bond respectively have finite moments. In the first example of CCl_4 the zero moment bespeaks a tetrahedral arrangement for the Cl atoms around C, in accordance with the well known Vant Hoff concept. Indeed the zero moment of a molecule, wherever definitely established is a very important and significant quantity. Thus the zero moment found for p-dichlor and sym. trichlor benzene, is in conformity with the arrangement of the 6 C-atoms of the benzene ring at the corners of a regular hexagon and in a plane with the chlorine atoms.

$$\mu = 0 \qquad \mu = 0$$
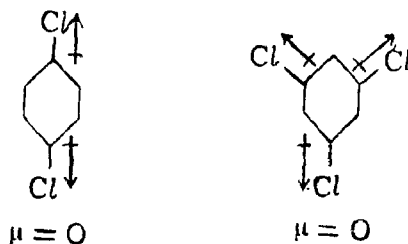
Similarly also the zero moment of 1:5 — and 2:6 — dichlor naphthalenes is in conformity with a plane structure for naphthalene.

$$\mu = 0 \qquad \mu = 0$$
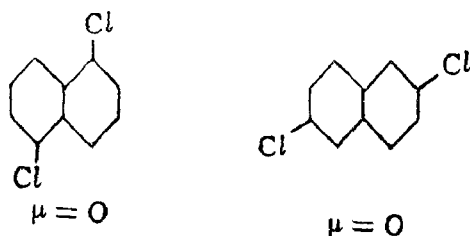
The zero value found for pp'/dichlor-diphenyl definitely decides in favour of a linear arrangement of the two phenyl rings, as opposed to the bent formula suggested at one time by Kauffler.

$$\mu = 0$$

Kauffler's formula with finite value for moment.
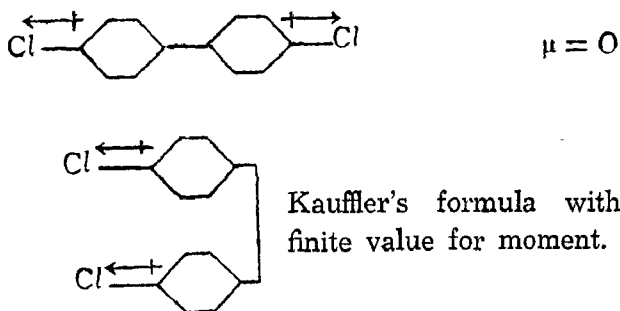
Again, the zero value for p-di-nitro-benzene indicates that the moments situated at the two -C-NO$_2$ groups balance
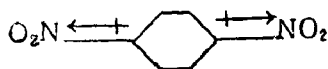
each other out exactly and act therefore along the diagonal axis of benzene ring. This is a significant fact as it shows that the two oxygen atoms in each of the NO$_2$ groups are symmetrically bound to the nitrogen atom. But, according to the ordinary valence concepts, one oxygen atom should be bound by a double bond, and the other

by a highly polar co-ordinate link.   Such an arrangement will lead to an axial dissymmetry in the NO_2 group (Rau and Swamy 1935).   It has therefore been suggested that the two oxygen atoms interchange their link types, and indeed so rapidly that for all purposes each bond is identical with the other and a mean of the two types.   In other   words,   the   two   forms   of $-NO_2$ group

$$-N\underset{O}{\overset{O}{\diagdown}} \qquad \text{and} \qquad -N\underset{O}{\overset{O}{\diagdown}}$$
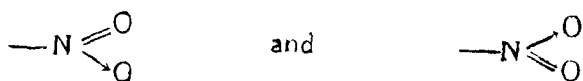
are said to be in " resonance ", a mode in which it is now understood many molecules exist, as will be described later.

The " electromeric " passage of an electron from the phenyl ring through the $N = O$, to the $= O$ atom, will also contribute to this symmetry: thus
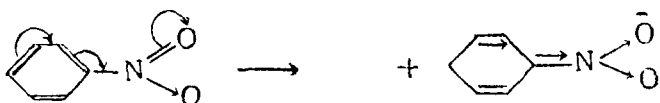
It is found that p-di-isocyano benzene has a zero moment and this is again significant for the structure of the $-NC$ group. For, if as postulated by Nef, the carbon atom in the isocyano group was divalent, then the two radicles will be unsymmetrical about the $C-N$ bonds in the para positions and inclined to them at an angle of 125° and there will be a resultant moment.

Nef's formula, with μ finite

$\mu = 0$
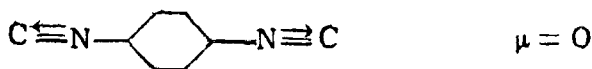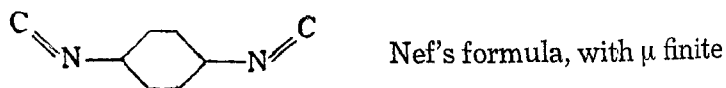
The observed zero moment shows that the C and N atoms must lie in a line and this can be best accounted for only by assuming an additional semi-polar type of link between the N and C atoms making the bond a triple link and thus set at 180° to the single link. Similarly also the zero moment found for $Ni(CO)_4$, indicates that the link between C and O is collinear with $Ni - C$ link and there-

fore must be triple in nature, two bonds being covalent and the third semi-polar.

$$
\begin{array}{c}
O \\
\parallel\mid\uparrow \\
C \\
\mid \\
O \leftrightharpoons C \text{---} N\mathfrak{l} \text{---} C \rightleftharpoons O \\
\mid \\
C \\
\parallel\mid\downarrow \\
O
\end{array}
$$
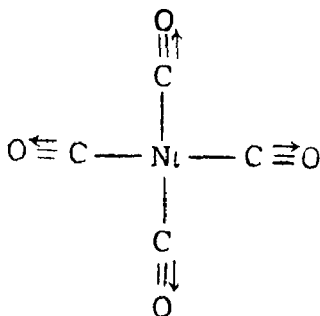
Recently a new compound of boron and nitrogen has been synthesised in Prof. Alfred Stock's Laboratories at Karlsruhe, of empirical formula $B_3 N_3 H_6$, which has a remarkable stability and certain other properties bearing a close resemblance to benzene and its derivatives. Indeed it has been named "Inorganic benzene", and all chemical evidences point to a formula

$$
\begin{array}{c}
NH \\
HB \diagup \diagdown BH \\
HN \diagdown \diagup NH \\
BH
\end{array}
$$

In full accordance with the symmetry of this formula, it has been found that the molecule possesses a very negligible and almost zero dipole moment (Ramaswamy, 1935,).

A rather interesting case of zero moment is to be found in penta erythritol tetrachloride. On the analogy of penta erythritol, which has a moment of approximately 2×10^{-18}, the tetrachloride should also have a moment since the $-CH_2Cl$ group has a non-axial and therefore unsymmetrically situated moment. The only explanation would seem to be that the four $-CH_2Cl$ groups in this molecule are held in a symmetrical and non-polar configuration around the central carbon atom by steric influences.

It is to be noticed also that all saturated hydrocarbons however large or complex, have zero moment. This is due to the fact that each CH_3 group moment balances out a CH bond moment, as is evident in methane, so that any CH_3 group in a hydrocarbon molecule can · be considered to be replaceable by H and thus the molecule finally

reduceable to an equivalent methane structure with moment zero. Fig. 9.

Fig. 9
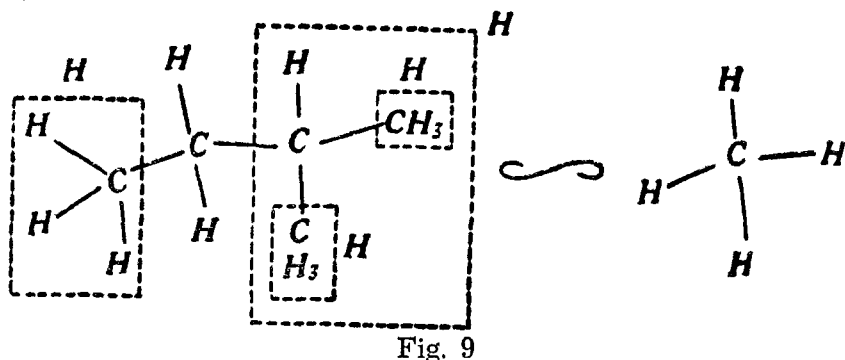
(b) *Finite moment values : Group moments.*

The finite value of moment as determined experimentally for any molecule, gives only the magnitude but not its direction inside the molecule. In general it is found that each chemical radical or group can be identified with a characteristic moment, since, neglecting small differences, the moment in a homologous series is virtually constant. The relative directions of the moment in different symmetrically formed group substituents, can then be established, since when they are symmetrically placed as in the para positions of benzene, the resultant moment will be either a difference $x-y$, when the group moments x and y have similar directions, or a sum of $x+y$, if they have contra directions.

$$\mu = x + y \qquad \mu = x - y$$
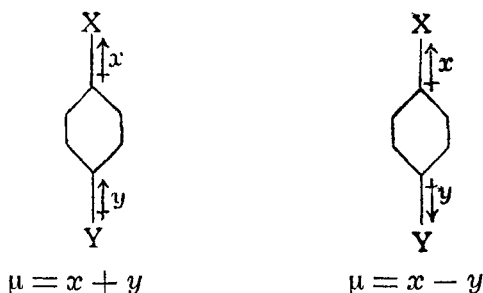
In order to determine the absolute directions, J. W. Williams (1928) proceeded on the practically certain assumption that in nitrobenzene, on account of the presence of an effective semi-polar link in the NO_2 group the moment is directed away from the benzene ring. This assumption is supported by the fact that the directions deduced for the other group moments such as C — Cl etc., are all in the right sense. There is however some doubt about both the value and the direction of the small C — H moment. According to Fuchs and Wolf, (1935) and Trieschman, (1936) the C-atom may be the positive end of the dipole, but Smyth (1937) has recently en-

deavoured to remove this doubt and to establish the widely accepted idea that in normal C — H as in saturated compounds, the C-atom is the negative end. It would seem however that when the C — H is adjacent to a double or triple bond, as in

$$\mathrm{=C}\!<\!{}^{\displaystyle \mathrm{H}}_{\displaystyle \mathrm{H}} \qquad \text{or} \qquad \equiv \mathrm{C-H}$$
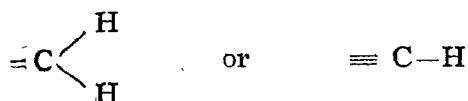
the H-atom is the negative end. This is due to some effect like an electron pressure in the multiple link, which counteracts the electron attracting power of the more positive C-atom in the C — H bond. (de Bruyne Davis and Gross, 1932; Gorman Davis and Gross, 1938). These conclusions regarding the absolute directions of moments are in general confirmed by the ionisation potential measurements of Mulliken, referred to in the last chapter (page 6): thus in CH_3I, the I-atom is the seat of the negative excess charge.

TABLE 5.

Group.	C_6H_5-		CH_3-		C_2H_5-		angle.
	gas.	solution.	gas.	solution.	gas.	solution.	
—CH₃	0·35	0·4	0		0		180°
—H	0		0		0		0°
—OCH₃		1·23	1·30		1·14	1·29	55°
—OC₆H₅		1·14		1·23		1·28	59°
—SCH₃		1·27		1·40		1·57	(70°)
—NH₂		1·53	1·23		1·2		
—I		1·30	1·59	1·60	1·9	1·9	0°
—Br	1·70	1·52	1·78		2·02	2·0	0°
—Cl	1·72	1·55	1·86		2·03		9°
—F	1·57	1·43	1·81		1·92		0°
—OH		1·56	1·68	1·66	1·70	1·70	62°
—CH₂Cl		1·85	2·03		2·05	2·10	67°
—CHCl₂		2·04		1·98		2·06	48°
—CCl₃		2·11		1·57			0°
—COOCH₃		1·9		1·74		1·74	
—CHO		2·75	2·70			2·40	58°
—COCH₃	3·00	2·90	2·8	2·74		2·76	58°
—NO		3·18					
—CN	4·39	3·92		3·4	4·09	3·4	
—NO₂	4·21	3·95	3·42	3·08		3·2	0°

Table 5 (Smyth 1937) gives a list of group moment values and their orientations in the group. In order to make these moment assignments more useful for comparative purposes, three pairs of values are given as far as possible for each case to include the methods of measurement and the molecular constitutive influences. With the aid of this table when there are more than one group moment present in a molecule, the resultant moment can be in general calculated by the method of vectorial addition. Thus the moments of meta, and para substituted diderivatives of benzene, as found, and as calculated by assuming an angle of 120° and 180° respectively, according to the formula $\mu = \sqrt{m_1{}^2 + m_2{}^2 + 2m_1 m_2 \cos \theta}$ show a general agreement.

TABLE 6.

C_6H_4XY		Ortho			Meta			Para		
X	Y	obsd.	calcd. i	calcd. ii	obsd.	calcd. i	calcd. ii	obsd.	calcd. i	calcd. ii
Cl —1·55	Cl	2·37	2·67	2·33	1·48	1·55	1·42	0	0	0
NO_2 —3·95.	NO_2	6·00	6·83	5·84	3·79	3·95	3·83	0	0	0
Cl	NO_2	4·30	4·91	4·53	3·39	3·44	3·36	2·53	2·40	2·51
NO +0·4	CH_3	3·66	3·76	4·50	4·17	4·16	4·38	4·44	4·35	4·55

When however such calculations are carried out for moments situated very near to each other, as in the ortho positions of benzene, there is considerable discrepancy between the observed and calculated values. This is clearly seen in Table 6. Such a discrepancy is also strongly evident in the case of CH_2Cl_2 where the two C — Cl dipoles are attached to the same C atom. Here the observed moment is much lower than the value calculated with $1·85 \times 10^{-18}$ for each moment, and a valency angle of 110° between them.

	observed.	calcd. i.	calcd. ii.
CH_2Cl_2	1·57	2·13	1·71

In order to account for these low observed values it was originally assumed that the valency angles were spread out to more than 60° and 110° respectively in the above two cases, on account of steric and other repulsive effects. It is now known however that

the effect is primarily due to intra molecular induction. Such induction effects can be calculated with the aid of the dipole field equations given on page 15 in connection with the evaluation of solvent effects, assuming suitable values for the polarisability and the mutual distances. Such calculations were for the first time carried out by Smallwood and Herzfeld (1930), for the case of benzene derivatives, and have since been elaborately employed for a number of molecules by Smyth and McAlpine (1933), LeFevre (1936), (1937) (1938), and Groves and Sugden (1937) (2), (1938). The moments as recalculated by this method are given for all the above cases under the head "Calc. ii". One can in a general way, visualise these induction effect corrections, e.g., in ortho disubstituted benzene, each dipole falls outside of the " 55° cone " of the other, (p. 16), and thus has its moment reduced by induction (Fig. 10). In methylene dichloride however (Fig. 11) the two $C — Cl$ moments fall within these cones and therefore have positive induced moments but as these are opposed to the original $C — Cl$ moments, the net moment is again reduced.

Similar induction effects are also responsible for the generally observed small rise in moment, as we go up a homologous series. Table 7.

TABLE 7.

	Cl.		CN.	
		△		△
Methyl	1·87	—	3·94	—
Ethyl	2·05	+·18	4·04	+·1
n.Propyl	2·10	+·23	4·05	+·11
n.Butyl	2·11	+·24	4·09	+·15
n.Amyl	2·72	+·25		

The rise in moment soon reaches a limiting value by the 4th or 5th carbon atom, when measurements are carried out for free molecules in gaseous state, but when the measurements are carried out in solution, the limiting steady value is reached much earlier. Both results are easy to comprehend. In the first case, it is evi-
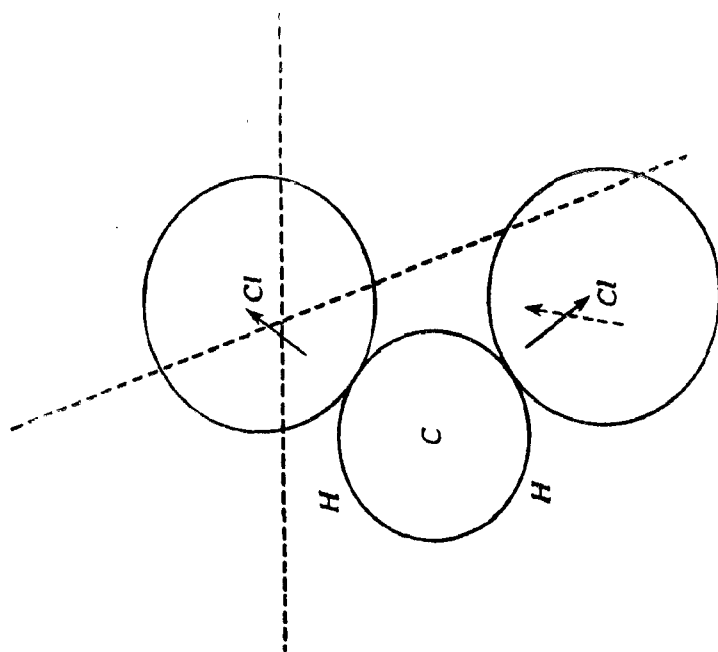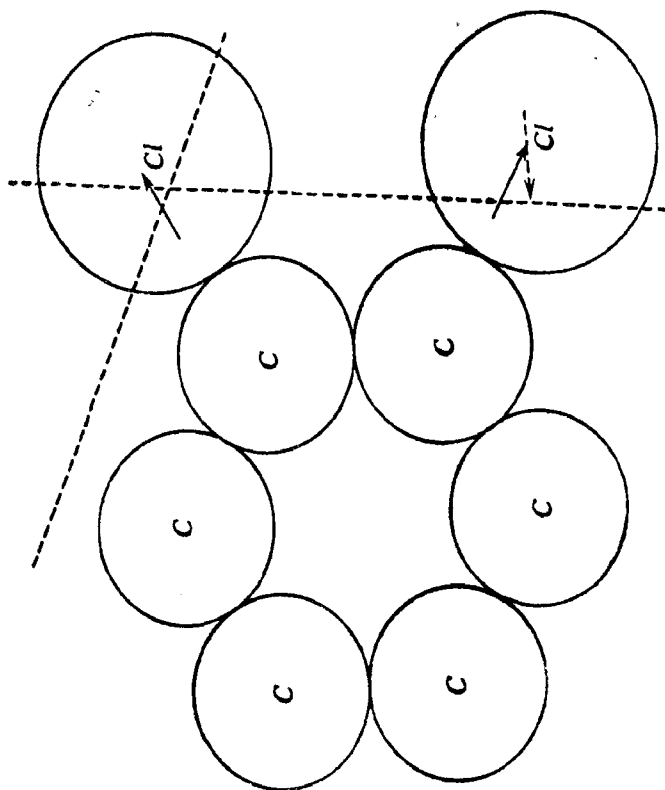
Fig. 10.
O—dichlorobenzene

Fig. 11.
Methylene dichloride.

——→ Bond moment
— — → Induced moment

(For clarity only one of the two mutual induced moments is shown).

dent that the growing carbon chain will add at first to polarisable matter in a region within the " 55° cone " space (fig. 12) in which the induced moment will be in the same sense as the primary dipole. The net induced moments in the carbon atoms further away are negligible but may be either positive or negative, the latter because these distant atomic groups can get outside the " 55° cone " region (Fig. 13) by virtue of the free rotation possible about the connecting single bonds. [Cowly and Partington, (1938), Groves and Sugden, (1937)]. The *size* of the end dipole group also determines the extent to which parts of the molecule lie within or without the " 55° cone." This induction effect has been termed " radical effect " in order to distinguish it from the " solvent effect " which is present when the moment is measured in solution. As this latter is in general always negative and therefore opposed to the " radical effect ", the limiting value is reached much earlier in the case of the measurements carried out in solution.

STRUCTURE FACTORS FROM MOMENT VALUES

In the case of a molecule with two known component dipoles, the angle between them could be calculated from the measured total moment. It is however essential in such calculations to see that the dipoles are sufficiently separated from each other so as to have no mutual induction effects. Otherwise, we will arrive at wrong values for the angle, as e.g. in $CH_2 Cl_2$ (p. 34). For similar reasons the oxygen valency angle calculated from the moment values in $CH_3 - O - CH_3$ will also be in error. These difficulties arising from proximity have been got over, by the simple artifice of using for the angle calculations group moments situated further away, but in the same valency direction, as in compounds of the type
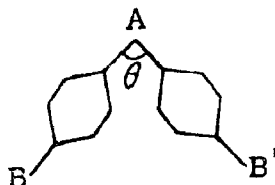
where A may be CH_2, O, S, or NH, and B and B′ are preferably identical and symmetrical substituents. The angle θ is then obtained from the moment values for three compounds of the type,
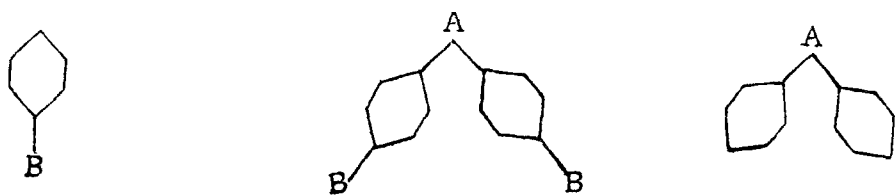
A great variety of such calculations are possible. [Bergman, Engel and Sandor (1930), Hampson and Sutton (1933), Hampson, Farmer and Sutton (1934), Smyth and Walls (1932) (2)]. Thus to calculate the angle θ between the moment in the group $-CH_2Cl$ and the $C-C$ axis in $C_6H_5CH_2Cl$, the moment values a, b, and c, of the three compounds could be utilised as indicated in (iv).

(i) $\mu = a$ (ii) $\mu = b$ (iii) $\mu = c$ (iv)
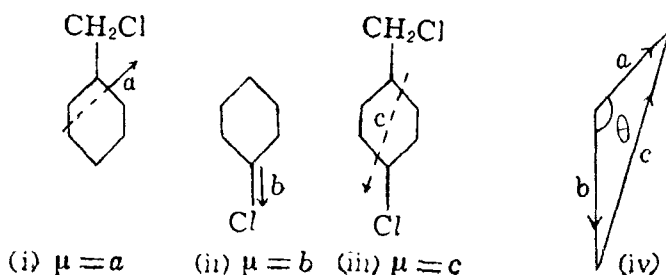
It is to be remembered that these angle calculations are still only approximate, as it cannot be considered that the mutual induction effects have been completely eliminated. Precautions have also to be taken to allow for what are known as " mesomeric moments ", which are caused by a special kind of interaction between a substituent and the phenyl ring. [Bennet (1934), Sutton and Hampson (1935)]. This influence will be described more in detail later.

SPECIAL STRUCTURE PROBLEMS

1. *Geometrical isomerism* :—This is obviously a simple case in which moment determinations will be very helpful. For, of the two possible isomers, the *trans* form
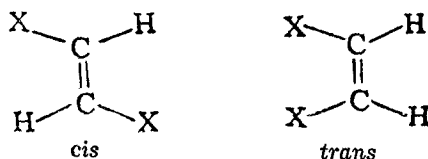
with a centre of symmetry, will have zero moment while the *cis* form will have a high moment. A large number of pairs of *cis*-*trans* isomers have been examined hitherto and the moments found
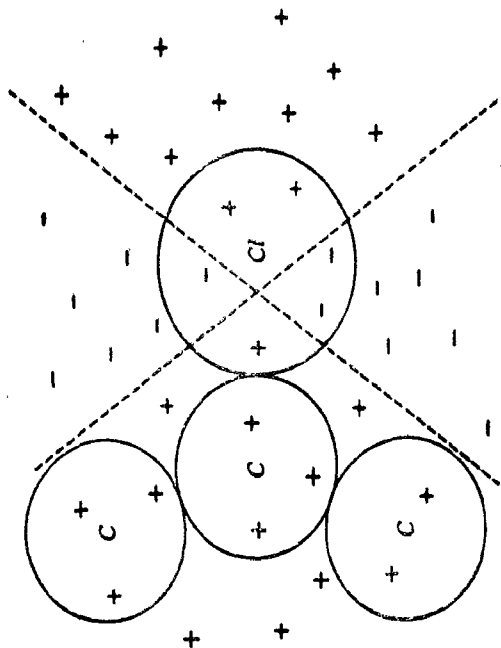
Fig. 12.
Isopropyl chloride

Fig. 13.
n-butyl chloride
[Origin of dipole ⅞ of C–Cl distance from C centre (Smyth)]

have been found to conform to the structures already assigned to them on chemical grounds. One exception where chemical and dipole evidences do not coincide is provided by chloro-iodo-ethylene. It has been claimed (Estermann, 1929) that the assignment of *cis* and *trans* forms based on dipole moment measurements is the correct one, and that the contrary conclusions from chemical evidences are not reliable. Another class of geometric isomers are to be found in the *syn* and *anti* isomers of the oxime series. There were once two opposing theories regarding the assignment of the configurations to the two isomers, one theory led by Hantzsch and Werner, and the other by Meisenheimer; the latter contended that in the Beckmann transformation of the oximes into the anilides, the groups that changed places were from *opposite* sides of the C=N bond. From a study of the moment of the N-ethers of the oximes of p-nitro-benzo-phenone, it has been possible to decide finally in favour of this view. (Sidgwick 1933).
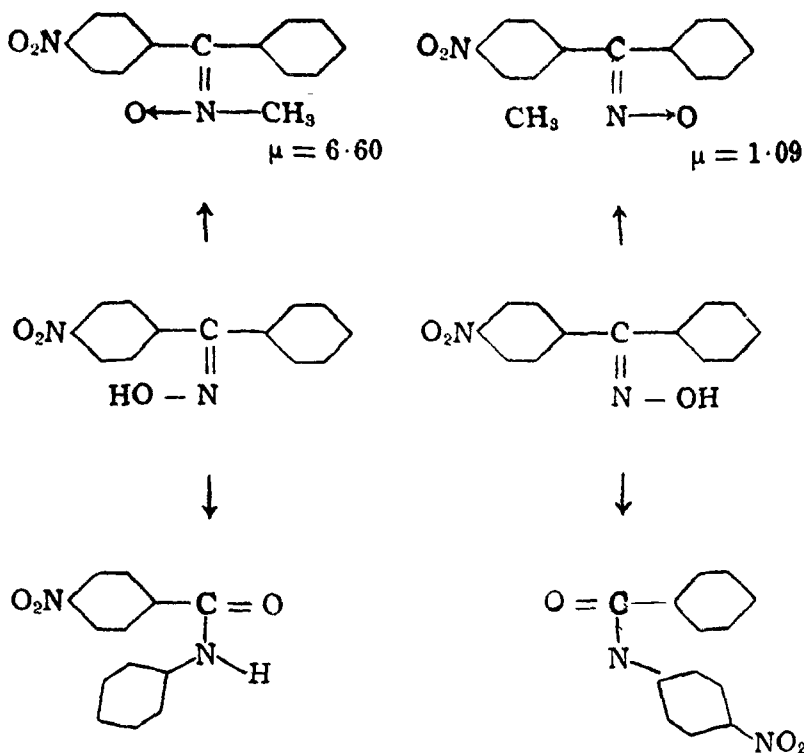
The configurations of the corresponding *cis* and *trans* isomers in the aromatic diazo compound series have also been recently verified by Le Fevre and Vine (1938) from dipole moment measurements on diazobenzene cyanide derivatives.

$$X-\langle\ \rangle-N$$
$$\|$$
$$NC-N$$

$$X-\langle\ \rangle-N$$
$$\|$$
$$N-CN$$
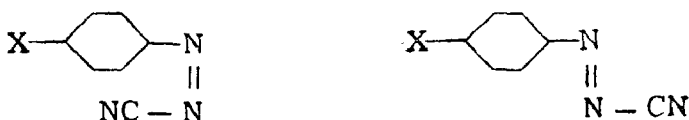
X	cis	trans
Cl	2·93	3·73
No$_2$	2·04	1·47

It is found that in each case the *trans* form is the more stable, the *cis* which is initially formed, spontaneously changing over into the *trans* form. Azobenzene itself has zero moment and has therefore the *trans* configuration. The corresponding unstable *cis* azo-benzene has also been recently prepared (Hartley, 1937). It has the expected high dipole moment, with a value of nearly 3.0×10^{-18} e.s.u.

2. *Heterocyclic and other complex Molecules.*—The spatial configurations of a number of complex molecules can be very elegantly deduced from a study of the dipole moment values of their parent structures and a few simple derivatives. The corresponding "chemical" methods, such as resolving into optical enantiomerides, are not always easy, and sometimes even very difficult to accomplish, as *e.g.*, in determining the spatial configuration of the allene system

$$\begin{array}{c} a \\ b \end{array} \!\!\! C = C = C \!\!\! \begin{array}{c} b \\ a \end{array}$$
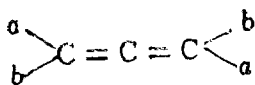
A few typical and interesting examples, where dipole moment measurements have been of considerable help, are given here with.

(a) *Compounds of type*

where X may be,

$$-N=,\ \underset{\overset{|}{\cdot}}{\overset{H}{-C}}=,\ -CH_2-,\ -S-,\ -Se-,\ -O-,\ or-NMe-.$$

6
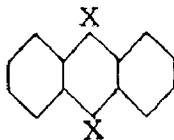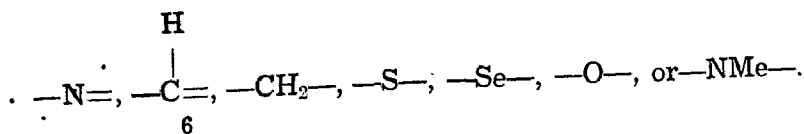
TABLE 8.

Substance		"X"	moment $\times 10^{18}$
Anthracene	..	H │ ⁀C⪦	0
Phenazine	..	⁀N⪦	0
Dihydroanthracene	..	H H ＼／ C ／＼	0·4
Diphenyl dioxide	..	⁀O⧵	0
Thianthrene	..	⁀S⧵	1·57
Selenanthrene	..	⁀Se⧵	1·41
Dimethyl dihydro phenazine	..	CH_3 │ ⁀N⧵	0·4

On the analogy of the plane symmetrical structures for the molecules of anthracene and phenazine, one might be led at first to expect that all similar compounds have also zero moment. But as seen from table 8, this is not the case. The observed appreciably high moments for thianthrene and selenanthrene, point to a concealed dissymmetry in the formula as usually written. This dissymmetry, as can be seen with spatial models arises from a folding of these structures about the x-x axis.   (Fig. 14 and 15)
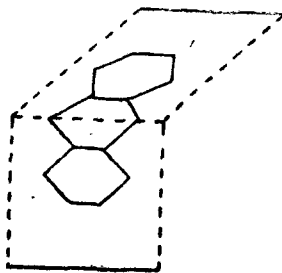
Fig. 14.

[Bergman and Tschudnaky (1932), Bennet and Glasstone (1934)]
The folding (with angle of 140° between the benzene planes)

Plate 1.
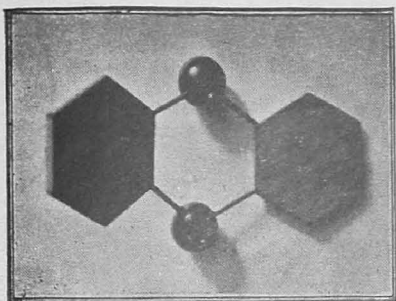
Fig. 15
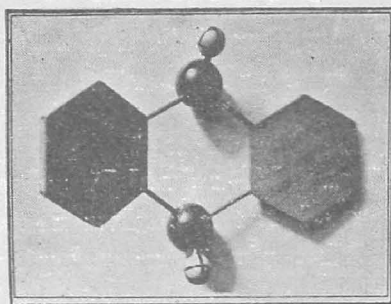
Fig. 16
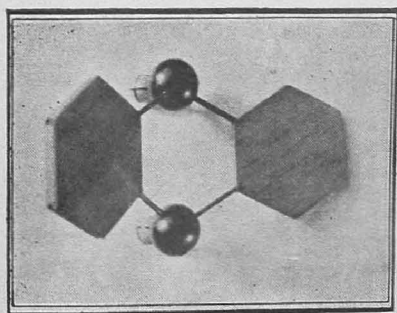
Fig. 17
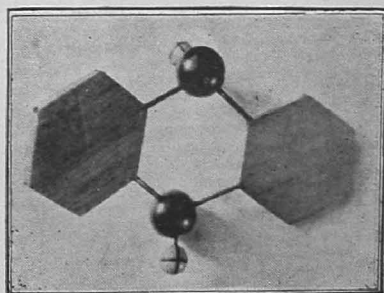
Fig. 18

is caused by the requirement that the valency angles of S and Se atoms must conform to the tetrahedral value of 110°. Apparently these angles cannot be maintained at 120° as will be required for a complete planar structure. On the other hand it seems that the valency angle for oxygen can take up the value 120°, as the moment of diphenylene dioxide is zero. A folded structure for 9 : 10 dihydro anthracene ($\mu=0\cdot4$) appears to be in conformity with an analogous structure suggested for tetraline from its dipole moment
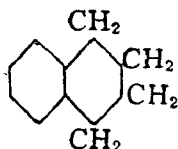
value, (Rau and Row 1935) and confirmed through Raman Spectra measurements, [B. Dayal Saksena (1938)]. The case of di-methyl dihydro phenazine is of special interest (Campbel, LeFevre, and Turner 1938) since the two Me groups can be (i) both inside the fold (Fig. 16) (ii) both outside the fold, (Fig. 17) and (ii) one inside and the other outside. (Fig. 18) A rough calculation shows that case (ii) (Fig. 17) is the most probable configuration which is compatible with the observed small moment of $0\cdot4\times10^{-18}$ e.s.u.

(b) *Fluorene and fluorenone.*
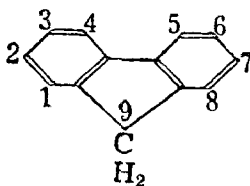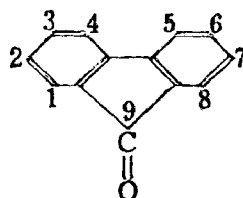
Fluorene   Fluorenone

The space configuration of fluorene is still an unsettled question. The problem is whether the two benzene rings are in the same plane with the pentane ring, or otherwise. Cook and Iball (1936) have considered all the x-ray, magnetic anisotropy and other measurements, and conclude that the two flat hexagonal rings of benzene are each folded at 20° about the common links to the plane of the pentagon ring to which they are attached. Such an arrangement should give rise to cis and trans modifications of fluorene and derivatives. Further, the simple 9 substituted derivative should occur in three stereo-isomeric forms. Bergmann (1930) has claimed to have succeeded in identifying some of these isomers, but his conclusions have been questioned. On the other hand the dipole-

moment measurements of Bergmann, Engel and Hoffmann, (1932) lend support to a *planar* configuration for the molecule. More recently Hughes, LeFevre and LeFevre (1937) have repeated the dipole moment measurements on fluorene and some more of its derivatives, (table 9) and conclude therefrom that the *bent* configura-

TABLE 9

Substance		moment $\times 10^{18}$
Fluorene	..	0·82
2:7 dinitro–fluorene	..	1·72˝ (approx).
2:7 dibrom–fluorene	..	0·22
Fluorenone	..	3·25
2:7 dinitro–fluorenone	..	4·80
2:7 dibrom–fluorenone	..	4·44

tion in which the two benzene rings are in addition deformed out of a regular hexagonal shape is more probable. However their observation that the moments of 2:7 derivatives of fluorene and fluorenone are not identical with the moments of the parent substances is not a convincing evidence against a planar structure. Le Fevre and Vine (1938) themselves have reported anomalous moments for 4:4' disubstituted diphenyl derivatives. Further the great reactivity of H in the CH_2 group in fluorene as compared with the CH_2 in di-phenyl methane, indicates that fluorene molecule exists " in a state of resonance " including some ionic forms, (See p. 54) and this will contribute an additional moment to the molecule. Thus the stereochemistry of fluorene is still an open subject.

(c) *The Allene system.*

In the allene system there are two double bonds in juxtaposition as in (i) and (ii)

$$\text{>}C = C = C\text{<} \qquad -N = C = N-$$

           (i)   (ii)
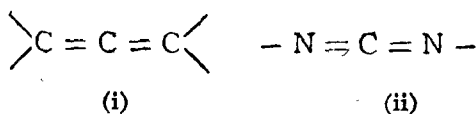
If one figures out this system with classical tetrahedral carbon models, it will be at once evident that in (i), the two planes each

containing one pair of the single links at either end of the molecule are perpendicular to each other. (Fig. 19, Plate 2). Correspondingly also in (ii), the two single end bonds will be found to be at right angles to each other. On the basis of this geometry of the system, a derivative of the type

$$\begin{array}{c} a \\ \diagdown \\ b \diagup \end{array} C = C = C \begin{array}{c} \diagup b \\ \diagdown a \end{array}$$
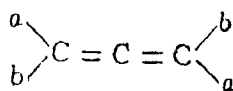
should be resolvable into optical enantiomerides. This was not achieved for a long time and indeed on account of this seeming impossibility Faltis, Pirsch and Bergman (1930) suspected a break down of the Vant Hoff structure for this case. Later Bergman and Hampson (1935) measured the moment of

αγ — di — (p — bromophenyl) — αγ — diphenyl allene,
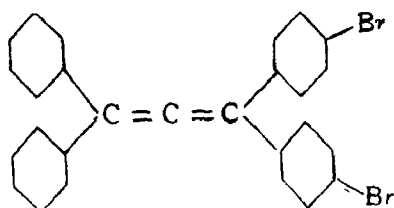
to be 1·92, just the value to be expected on the basis of Vant Hoff's orthodox stereochemical view. The alternative structures suggested by Faltis are thus decisively ruled out. Simultaneously with Bergman's work, Maitland and Mills also announced (1935) the successful resolution of αγ—diphenyl—αγ—di—(α—napthyl) allene.
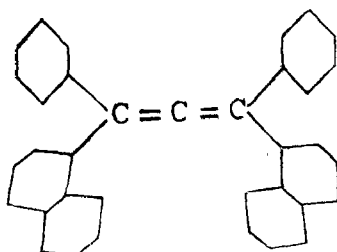
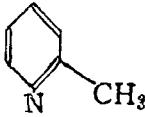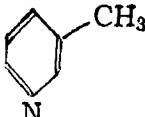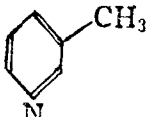
The dipole moment of carbo-dianil,
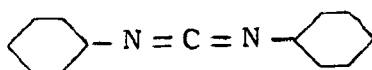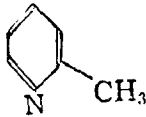
measured as 1·89, by Bergman and Schutz (1932), similarly supports the geometry of the allene system, the measured moment being

accounted for as the resultant of two moments of $1 \cdot 34 \times 10^{-18}$, at right angles to each other.

(d) *Pyridine ring.*

It is now known that benzene exists simultaneously in two principal isomeric forms, ("resonance"), as suggested by Kekulé. The corresponding and closely analogous pyridine ring also exhibits this isomerism. But as pyridine itself is a hetero-atomic polar ring, when a second polar group is introduced into the ring the two Kekulé isomers will have different moments, as calculated for example for the case of the α and β-picolines.

|		Calculated.	Observed.
$\mu = 1 \cdot 92$	$\mu = 2 \cdot 29$	1·78	1·72
$\mu = 2 \cdot 29$	$\mu = 2 \cdot 61$	2·18	2·30

Since the frequency of transition between the two forms is very large, the two forms are effectively superposed in dielectric measurements, and the observed moment is a vectorial mean of the two values. The close agreement found between the observed and calculated values may be somewhat fortuitous but it provides for the case of the picolines very strong evidence for the postulated Kekulé isomers in pyridine rings. [Rau and Swamy 1934, (1)].

(e) *Azides and aliphatic diazo compounds.*

This class of compounds forms another very interesting case in stereo-chemistry. The question has been frequently raised whether the three atoms of the azide group in the one, and the diazo radical in the other, are aranged at the corners of a triangle or linearly. In all, three alternatives are possible, each satisfying the octet rule. Thus
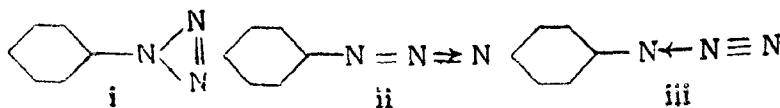

phenyl azide $\mu = 1 \cdot 55$.
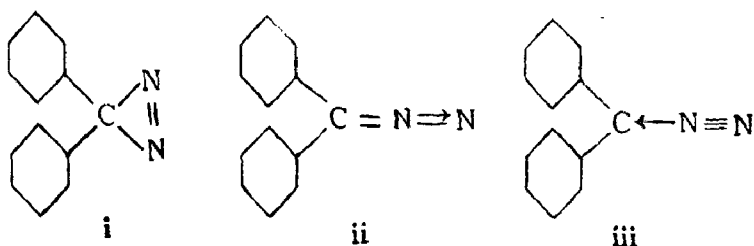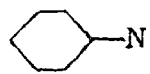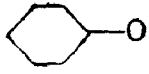
diphenyl diazo methane $\mu = 1\cdot42$.

Chemical evidence, and so also all physical measurements such as heats of formation, Raman spectra and electron diffraction, favour the linear arrangement, but do not decide between the two possible alternatives ii and iii.   The observed dipolements for both of these radicals are however too low for either of the structures ii and iii, each with one highly polar co-ordinate link in them.   Further, structure iii must have the positive end of the dipole directed outward and this postulate is not in agreement with the observed negative direction of the moment.   The low value for the dipolement can however be still reconciled with a linear structure, for the magnitude of the moment may be taken to indicate that both the linear forms ii and iii (with opposed moments) are present in such rapid tautomerism that they are superposed to give a low value. (Sidgwick, 1934).

3.   *Free rotation.*—According to classical concepts, based on chemical evidences such as the impossibility of separating any rotation isomers etc., molecules are in general considered to be flexible to rotation about any single bond as axis.   This aspect of molecular structure has come into prominence in dipole moment measurements since the time it was found that a few typical symmetrically substituted benzene derivatives such as
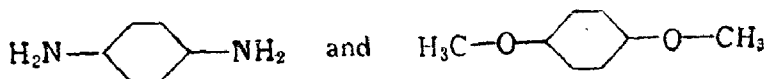
possessed definite dipole moments.

Here the moment in either or
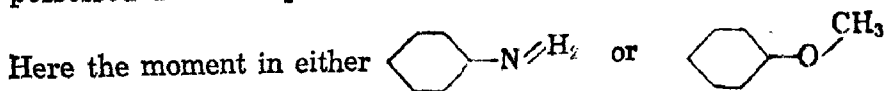
is not directed along the or axis,

and hence although identical groups are substituted in the para positions of benzene, the moments do not cancel out. There is a resulting moment which can take any value from zero for the symmetrical *trans* position of the two bent groups, to a maximum for the *cis* position. When both positions are possible the observed moment will be a mean value. In the particular case where such groups possess enough energy to be able to perform complete rotations in an *unhindered* manner about the connecting single bond, the resultant moment in the molecule will be given by

$$\mu^2 = \mu_f^2 + \sum_k \mu_k^2$$

where μ_f is the resultant of all the *axial components* of the rotating vectors and the fixed vectors in the molecule and μ_k the component of each rotating vector *perpendicular* to its axis rotation. (Zahn 1932). In favourable cases the resultant moment of any flexible molecule for each position of rotation of the components can be computed and the actually observed value compared with these calculations. One interesting example is that given by Kubo (1936), for the case of the moment of methylene glycol dimethyl ether (Fig. 20).
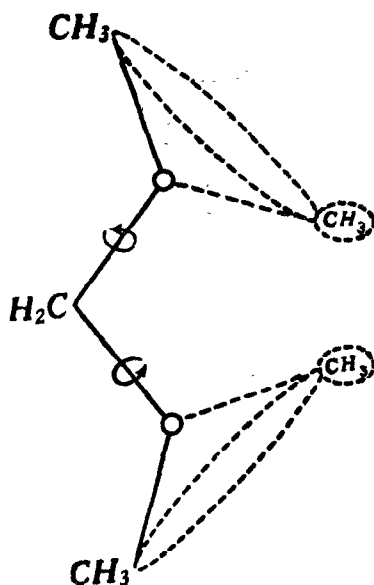

Fig. 20.

The figure correlating the various moment values with the angles of rotation resembles a contour diagram, and is reproduced here (Fig. 21). The moment for one extreme zig-zag position is 2·10 and for the other limiting "horse-shoe" position 0·89.

For a completely free rotation the value should be 1·73. The actually observed values are 0·74 at 34° and 1·13 at 200°.
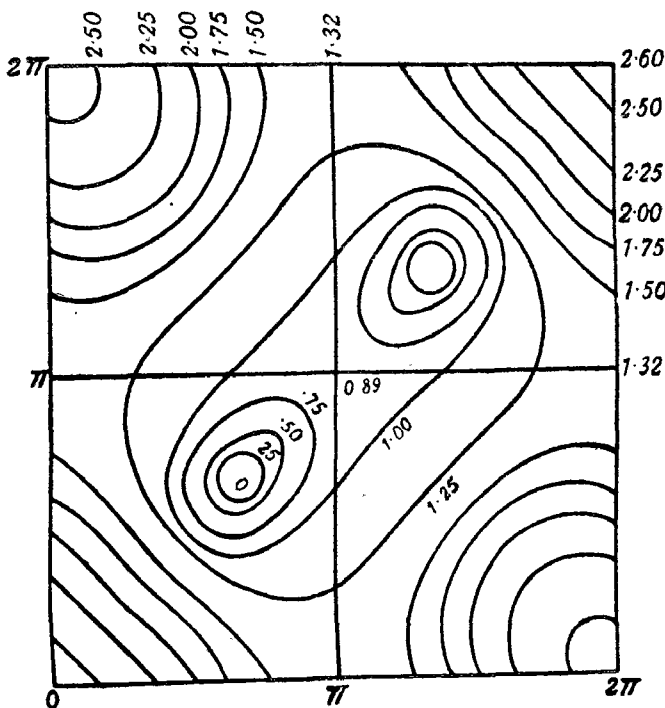

Fig. 21.

It is frequently found, as in the above case, that the observed moment does not correspond to a complete free rotation. This is particularly so, when the rotating groups are sufficiently near—within about 3 A°—to build up a considerable potential energy between them. In such cases free rotations are possible only if the thermal energy KT is about 10 times the mutual potential energy. In the case of a typical example like ethylene bromide
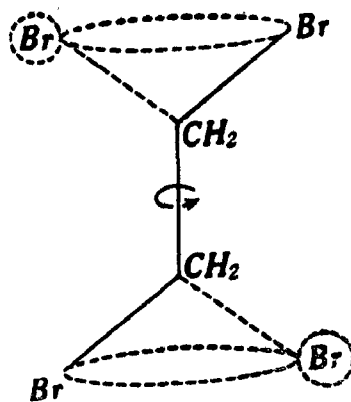

Fig. 22.

7

the thermal energy at room temperatures is only 1/10 of the potential, and therefore there is possible only a rotational oscillation about the position (trans) of minimum zero potential energy. At higher temperatures, and therefore for higher values of the energy KT, the amplitude of oscillation will increase. If, as is the case in the simpler type of molecules, the position of minimum potential energy corresponds to a zero moment or some other minimum value, then on account of the increasing amplitude of oscillation, the moment of the molecule will no more remain constant but increase with temperature, and the orientation polarisation will not follow the 1/T law. The dynamics of the system can be subjected to calculation, [Rau and Swamy 1934 (2)] and from the observed moment at any one temperature, the potential hump, or maximum of potential energy between the two groups can be calculated. The relation between the potential energy β and the moment μ is given by

$$\mu^2 = 2m^2 \sin\,\theta \left[1 + \frac{iJ_1 \left(i\dfrac{\beta}{kT} \right)}{J_o \left(i\dfrac{\beta}{kT} \right)} \right]$$

where θ is the angle between the group moment m and the axis of rotation. Table 10 gives the results of a calculation for the moments of $C_2H_4Br_2$ at different temperatures, starting with the β value found for one temperature. It will be seen that the calculated values agree with the observed.

TABLE 10

Temp.	μ in Benzene.		μ in Carbon Tetrachloride.	
	observed.	calculated.	observed.	calculated.
10°	1·13	1·13	0·86	0·87
20°	1·15	(1·15)	0·89	(0·89)
30°	1·18	1·17	0·92	0·91
40°	1·20	1·19	0·95	0·93
Potential Energy β in ergs.	$1·86 \times 10^{-14}$		$28·9 \times 10^{-14}$	

Plate 2.
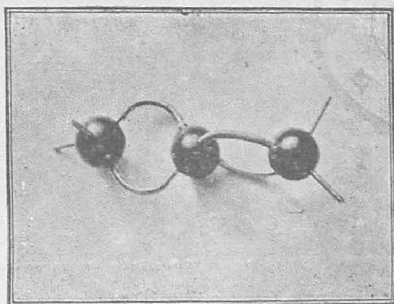
Fig. 19

meso
Fig. 23

active
Fig. 24

An interesting case is provided when there are more than one substituents in the two methyl groups of ethane, as in

$$
\begin{array}{c}
\text{Z} \quad \text{X} \quad \text{Y} \\
\diagdown \; | \; \diagup \\
\text{C} \\
| \\
\text{C} \\
\diagup \; | \; \diagdown \\
\text{X}' \quad \text{Z} \\
\text{Y}
\end{array}
$$

Here three "trans" positions of minimum energy are possible corresponding to each of the three substituents, with different energy barriers 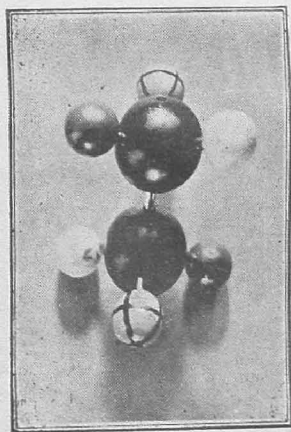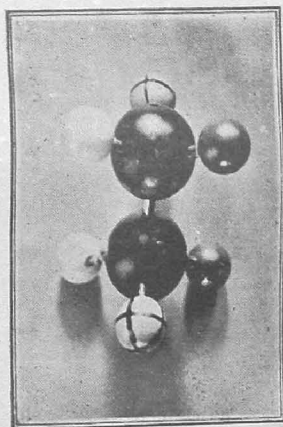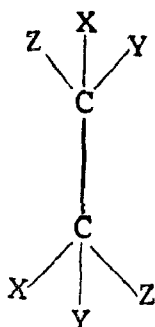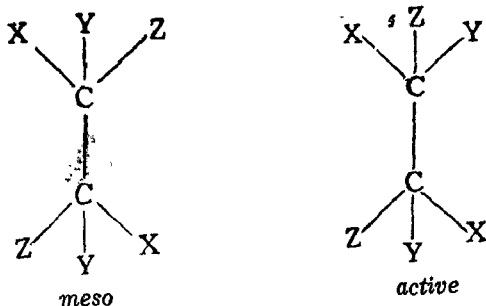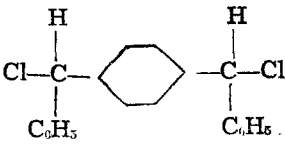between them [Rau (1934). Wolf and Bodenheimer (1931), Weissberger and Sangewald (1930)]. At ordinary temperatures, the compound will be a mixture of all three possible "rotation isomers", each oscillating in its energy trough. Such compounds have another feature as they can exist in two isomeric forms, one the optically *active* form, and the other the inactive internally compensated *meso* form. The latter is distinguished from the former by the possibility that one of the three *trans* forms can be completely symmetrical and therefore have a zero moment (Fig. 23, Fig. 24). As a consequence the *meso* form will have a smaller moment than the *active*.

$$
\begin{array}{cc}
\begin{array}{c}
\text{X} \quad \text{Y} \quad \text{Z} \\
\diagdown | \diagup \\
\text{C} \\
| \\
\text{C} \\
\diagup | \diagdown \\
\text{Z}' \quad \text{X} \\
\text{Y}
\end{array}
&
\begin{array}{c}
\text{X} \quad \text{Z} \quad \text{Y} \\
\diagdown | \diagup \\
\text{C} \\
| \\
\text{C} \\
\diagup | \diagdown \\
\text{Z}' \quad \text{X} \\
\text{Y}
\end{array}
\\
\textit{meso} & \textit{active}
\end{array}
$$

At higher temperatures or when the asymmetric groups are separated as in p-di (α-chlorobenzyl)-benzene, full rotation is possible and both moments will increase and approach each other in their value. Experimental values for a few pairs of active and meso compounds are given in Table 11. The existence of "rotation isomers" is also evidenced by other physico-chemical data e.g. optical rotation (Lucas. 1930).

TABLE 11

Substituent.			Moment.	
X	Y	Z	active	meso.
H	C_6H_5	Cl	2·75	1·27
H	$COOCH_3$	Cl	3·05	2·36
H	$COOC_2H_5$	OCH_3	3·73	3·33

	active	meso.
	2·48	2·28

Another interesting consequence of "free rotation" is to be found in long chain saturated compounds, with widely separated polar substituents. On account of the flexibility of the molecule around the several intervening single valency links, the two dipoles can orient themselves at random with respect to each other. The resulting moment of the molecule, will be just as if there were two independent dipoles present, ie., with

$$\mu = \sqrt{2}m.$$

where m is the moment of each group. The moment is then independent of the number of connecting links (Ebert and Hojendahl, (1932), Smyth and Walls (1932 (1)). Thus,

Decamethylene dibromide

$Br - (CH_2)_{10} - Br$, $\mu = 2·74 = \sqrt{2} \times 1·93$

Tricosane — 8 — 16 — dione

$$CH_3 - (CH_2)_6 - \overset{\overset{\displaystyle O}{\|}}{C} - (CH_2)_7 - \overset{\overset{\displaystyle O}{\|}}{C} - (CH_2)_6 - CH_3,$$
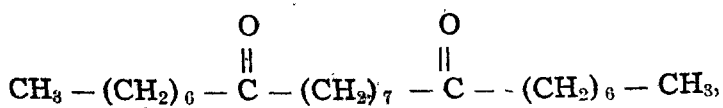
$$\mu = 3·6 = \sqrt{2} \times 2·55.$$

CHAPTER IV.

DIPOLE MOMENTS AND CHEMICAL REACTIVITY.

SOME "DIFFICULT" MOLECULAR STRUCTURES

In the concluding portions of the last chapter, we were dealing with the case of a number of molecules, whose structures could not be fully represented by a two dimensional formula, but required a three dimensional configuration in order to definitely characterise them. Atoms and groups in such molecules are capable of moving about, although in a prescribed path, but their movements and the resulting moments could be subjected to simple classical calculations. Frequently however, one meets with in chemistry, molecules which cannot be represented by any one single formula, on account of the fact that the bonding electrons between two atoms do not remain there but pass over to neighbouring atoms and bonds. It is found that the geometry of such molecules can only be tackled in an n-dimensional space, by employing the methods of wavemechanics. Such calculations have been carried out by Pauling (1933), Pauling and Wheland (1933) Pauling and Sherman (1933), Huckel (1931, 1937) Wheland and Pauling (1935), Lennard Jones (1936) Jones and Turkevich (1936) and Penney (1936), for some simple and symmetrical molecules. The most common and well-known type of such a molecule is benzene. In spite of the different formulae once proposed, and the synthetic organic researches of Mills and Nixon regarding the mobility of bonds [Mills and Nixon (1930) Sutton and Pauling (1935)], physical measurements on benzene and its important derivatives are found to be consonant with a postulate of approximately 1½ single bonds between any two of the ring carbon atoms. Kekule represented this in his famous structure of benzene as an equilibrium mixture of two isomers.
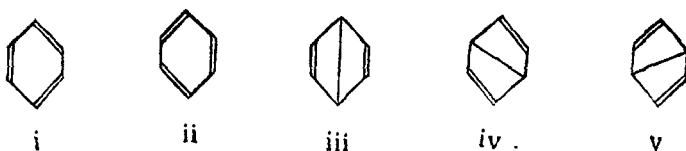

i   ii

Modern wave mechanics has successfully tackled this complicated "electron" dynamics and it has been possible to show that benzene is a "superposition" of not two, but five different states of the molecule, the first pair corresponding to the Kekule forms contributing 81% to the total.

i   ii   iii   iv .   v

Similarly, for napthalene forty-two different "canonical" states have to be considered, the first three unexcited states contributing 67% to the total.   When the 16 " first excited " states are included, nearly 98% of the "resonance energy" of naphthalene is accounted for.   For anthracene, there are 429 'canonical' structures!

' SUPERPOSED ' POLAR STRUCTURES.

Let us now consider the case of a typical *polar* molecule which belongs to this category, as e.g., dimethyl γ-pyrone. The moment of this symmetrical molecule, with dipole groups well separated can be easily calculated without much uncertainty.
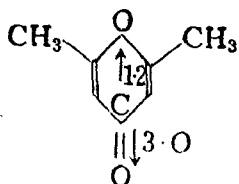
μ calculated $= 3 \cdot 0 - 1 \cdot 2 = 1 \cdot 8 \times 10^{-18}$ e.s.u.

Still, it is found that the value so obtained, $1 \cdot 8 \times 10^{-18}$ is much lower than the observed value of $4 \cdot 0 \times 10^{-18}$.   This violent departure from the value to be normally expected must no doubt be associated with the peculiar chemical characteristics exhibited by this molecule, such as that the ketone group has a depressed reactivity and does not form oximes and hydrazones.   From various other chemical evidences also it is found that the molecule frequently behaves as if it had a betain-like ionised formula.
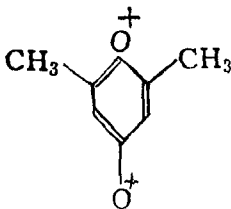
Thus here is a case where a molecule cannot be given any unique chemical structure.   Now the moment of this ionised or excited state can be approximately calculated as

$(5 \times 10^{-10}) (3 \times 1 \cdot 5 \times 10^{-8}) \sim 22 \times 10^{-18}$ e.s.u.

The observed high moment must therefore be due to the fact that the molecule can partly exist in this excited highly polar state. Indeed from the magnitude of increment in moment over the calculated value, a rough estimate can be made of the contribution of this excited state to the actual structure [Rau (1936)].

Thus if the actual state of a molecule can be represented by a wave-mechanical function ψ, and those of the contributing states by ψ_1 and ψ_2 with moments μ_{1x} and μ_{2x} respectively directed along a common axis x, then

$$\psi = \alpha_1\psi_1 + \alpha_2\psi_2$$

where α_1 and α_2 are the coefficients of the two states, and $\alpha_1{}^2 + \alpha_2{}^2 = 1$. Then
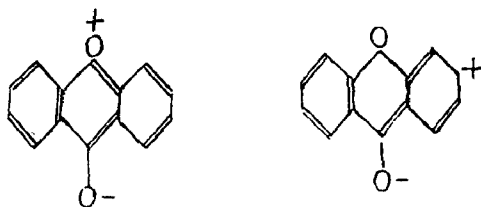
$$\mu = \alpha_1{}^2\mu_{1x} + \alpha_2{}^2\mu_{2x} + 2\alpha_1\alpha_2 e \cdot \int_{-\infty}^{+\infty} \psi^* \sum_{i=1}^{n} x_i - a \quad \psi_2 d\tau$$

The third term in the above expression can be neglected, and thus from μ, μ_1 and μ_2, the fractional importance of any one state viz.,

$$\frac{\alpha_1^2}{\alpha_1^2 + \alpha_2^2} = \alpha_2^2$$

can be calculated. In dimethyl γ-pyrone, the calculated coefficient of the excited state is 15%.

In more complicated molecules such as xanthone, a number of excited states are possible, such as

It is to be noted that the resultant moment of the molecule in these cases is a *vectorial* mean of the moments of the parent states and not a mean square value, such as it would be were it a case of simple mixture of tautomeric isomers. In the latter event, with the period of isomerisation larger than the relaxation time of the molecule in the alternating electric field i.e., greater than 10^{-10} to 10^{-12} sec, the observed moment will be *numerically* between the two

values, irrespective of the direction of the moment.   But it is observed that this is not   the case in several instances where superposable resonance states have to be postulated. Thus, in the case of the α-picoline (page 46) the moments of the two alternative structures are 1·92 and 2·29, while the observed value is lower than either *ie.*, 1·72.   Again, in the case of chlorobenzene, the moment of the normal molecule would at first be expected to be 1·85, corresponding to the aliphatic C-Cl moment ; but chlorobenzene can also exist in excited states of types i and ii,


i   ii
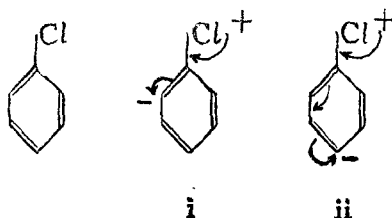
with moments of the order of 10.   The observed value will therefore be between 1·85 and 10, if it were a case of mixture of two rather slowly changing tautomerides.   The actual value of 1·5 shows that the moments of the excited states, which are in the opposite sense to the normal moment are superposed on the latter adding up vectorially to give a lower value.

OTHER EFFECTS OF "SUPERPOSITION" OR "RESONANCE"

On account of this "superposition" of structures, changes are produced in the characteristic lengths of interatomic bonds. [Pauling, Brockway and Beach (1935), Penney (1936)].   Thus, in benzene, the C—C distance is 1·45 A°, a value between 1·33 and 1·54 which are the characteristic double and single bond lengths respectively. Such an intermediate state of the bond can also be described by the statement that the single bond has "a partial double bond character."   When there is such a superposed double bond character, the normal freedom of rotation about the single bond is also restricted and the molecule is fixed or "frozen" into definite forms. [Sutton (1934), Zahn (1934), Marsden and Sutton (1936)].   A common example where this happens is the carboxylic COOR group where, on account of the excited state, the—OR is *fixed* in a *cis* position to the C = O, this being the more stable of the two alternative geometric isomers. Such a "freezing" also occurs in the di-phenyl compounds, the connecting link between the phenyl rings having in general an appreciable double bond character on account of

resonance.   The free rotation of the two rings about the connecting single bond is thereby considerably hindered.
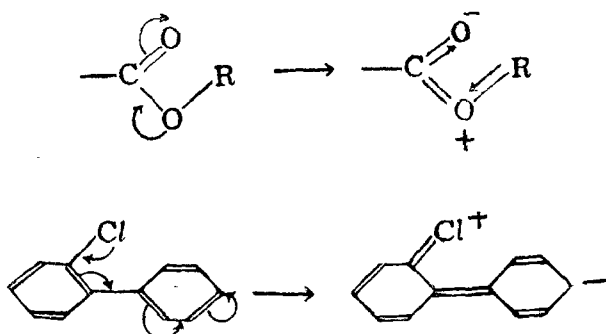
ACTIVATION OF MOLECULES: MESOMERISM.

Any chemical reaction is ultimately electrical in nature, all reactions being preceded by an excitation of the reacting molecules. It is therefore of great interest to study the nature of the excited states such as those reported above, since the course of any reaction must depend upon the character of the excited state of the molecule. Thus, in the case of the mono halogenated benzenes, the molecules can get excited only so as to have a negative charge at the ortho and para positions. (p. 56).

These positions are therefore the main seats of reaction, and ortho and para substitution products will be formed on further halogenation etc. Extensive studies on these lines, have been carried out particularly in the case of the substituted benzenes by Robinson, Ingold and their students. [Robinson (1932), Ingold (1934): see also Wheland and Pauling (1935)]. The net partial excitation of a molecule is generally known as "mesomerism," and the effect produced by a subtituent as "mesomeric effect." These excitation characteristics are

observed to conform to certain general rules such as: (i) in $\bigg\rangle C = O$

group the oxygen atom always tends to take up a negative charge

from the double bond, forming thereby $\bigg\rangle \overset{+}{C}-\overset{..}{O}\,$; (ii) in $\overset{O}{\underset{C}{\diagup}}\overset{}{\diagdown}{C}$

group, one non-bonding electron in the oxygen atom tends to get into a bonding state, leaving a positive charge on the oxygen and thus

leading to $\overset{\overset{+}{O}}{C \diagup \diagdown C}^{-}$.(iii) Cl, N, and other atoms with non-bond-

ing electrons in their outer shell, always tend to take up a positive charge by donating one of these electrons to a bonding state, as e.g. in chloro benzene. Such a "flow" of electrons is known in the literature as "electromeric flow," and is particularly favoured when two groups such as (i) and (ii) one acting as an electron "sink" and the other as an electron "source", are present at suitable positions in the same molecule. It is found that in general a path formed of a conjugated system of double and single bonds is ideally favourable for transmitting this flow, e.g., γ-pyrone.

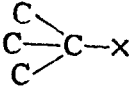Benzene is a very favourable case for studying electromerism, as the conjugate system forming the phenyl ring acts virtually as a loose electron mass, which can serve both as a " sink ", when in chemical contact with electron donating substituents, and as a " source " when in chemical contact with electron accepting reagents. Whenever there is a tendency for a flow of electrons into the ring, the ortho and para positions get excited while when the converse is the case, the meta positions are relatively more reactive. Thus

o p   m   m   reactivity.
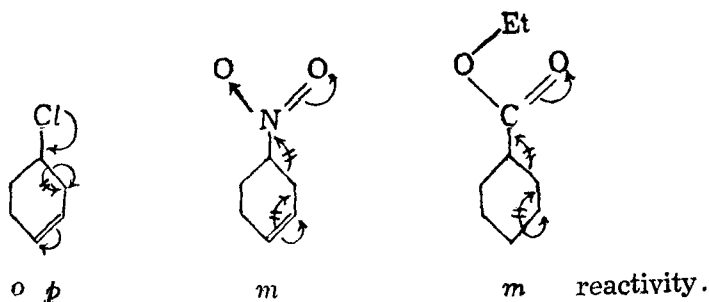
Such a flow of electrons, however partial it may be, leads to an additional permanent electrical dissymmetry in the molecule, and therefore gives rise to an additional dipole moment. This is known as "mesomeric moment", and is generally assigned in the case of benzene derivatives a negative sign when the flow is *away* from the ring and a positive sign when the flow is *into* the ring. This additional moment is manifested as a vectorial difference between the value of the group moment when attached to a benzene ring and that when attached to a tertiary aliphatic carbon atom. The magnitudes of these mesomeric moments are usually quite appreciable and of the order of bond moments: Table 12. [Sutton (1931)].

TABLE 12.

×	—x			Orientation
—Cl	—1·56	—2·15	+0·59	
>O	—1·08	—1·29	+0·45	ortho.
—NH₂	+1·55	+1·23	+0·32	para.
—C≡N	—3·89	—3·48	—0·43	meta.
—NO₂	—3·93	—3·05	—0·88	

The sign of the mesomeric moment incidentally provides a simple criterion for predicting in general the course of substitution reaction. Care should be taken however to see that subsidiary effects such as those due to induction (p. 35) are also taken into consideration, as this may sometimes be in the opposite sense to the "mesomeric moment," as for e.g., in the case of chlorobenzene.

Induced I.   Mesomeric M.

VELOCITY OF REACTIONS

The velocity of a reaction is affected by the facility with which electrons are available or not at the reaction centres. There are other specific influences also affecting the velocity. It has been found that in the case of aromatic compounds, the changes in reactivity which result from the introduction of further substituents in the molecules (O positions being excluded) are largely due to the changes in the energy of activation E in the well known velocity equation.

$$V = P \cdot Z \cdot e^{-E/RT}$$

And this energy of activation, as e.g. in the alkaline hydrolysis of ring substituted benzoic esters, has been found to be related to the

dipole moment of the substituent group, and indeed an empirical equation of the form

$$E = E_0 \pm C(\mu + \alpha\mu^2)$$

is found to correlate the velocities observed with different substituents in the meta or para positions. [Watson (1937), Hertel and Dumont (1935)].

In concluding these lectures, it is appropriate to make some remarks on the "practical use" of such studies. This question of the "practical use" of science is of peculiar interest to India, and has been frequently misjudged. If the History of Science teaches us one thing pointedly, that is the great value attached to disinterested research. Strangely this year in the United States this same question has been the theme of a number of talks and I will content myself by giving references to some of them; Gibb (1937) Sarnoff (1937) Kettering (1938); See also Irvine (1938).

Coming to the subject of these lectures, the purely disinterested studies of electrical polarisation of materials, their temperature coefficients etc., can and have been put to "practical use" in a number of ways. There are now in the market, ready made instruments which use the principle of dielectric measurements for determining moisture content of solids, controlling of distillations, and for estimating the purity of liquids, raw materials, semi and final products. Such apparatus can also be used for quantitative and rapid water estimations, detecting *traces* of moisture in transformer oils, controlling adulteration of oils, measurement of particle size of powders etc., etc., [Ebert (1934), Bull and Zwecker (1934)].

Surely, when Debye sought to explain a hitch in the theory of Clausius and Mosotti he had no 'practical aim' at finding a convenient method for " detecting traces of moisture in transformer oils! "

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