Patrika

July 1988 No. 17 Newsletter of the Indian Academy of Sciences

54th Annual Meeting

At the invitation of the Indian Association for the Cultivation of Science, Calcutta, the 54th Annual Meeting of the Academy will be held at Calcutta on Monday 31 October and Tuesday 1 November 1988.

The scientific programme will include lectures by Fellows and Associates of the Academy, two evening lectures and a discussion meeting.

The Discussion Meeting on 'India's Nuclear Energy Programme' will include talks by K. Sriram, S.D. Soman, Praful Bidwai and M.R. Srinivasan.

The evening lectures will be on "Recent developments in the physics of liquid crystals" by S. Chandrasekhar and "Science & Technology and their Human Roots" by D.P. Chattopadhyay.

The following is a provisional list of lectures by Fellows and Associates.

Repair of DNA damage in *Vibrio cholerae* – J. Das

Meiotic Chromatin – M R S Rao
Recent developments in neuro-oncology – Chitra Sarkar
Some recent advances in digital signal processing – S C Dutta Roy
Borel determinacy – T Parthasarathy
Quantum mechanics and chemical valency – M S Gopinathan
The electronic structure of high T_c cuprates – D D Sarma
Clays: Nature's gift to the chemist – P K Ghosh
Material deformation at high strain rates – G Sundararajan
Foundations of quantum mechanics: Open questions and new challenges – D Home
The statistical mechanics of microemulsions – R Pandit
Disturbing the de-Sitter universe – N Panchapakesan
Proterozoic chronology and evolution of the Singhbhum region – D Mukhopadhyay

As reported in Patrika 16, the birth centenary of Prof. Sir C.V. Raman and the diamond Jubilee of the discovery of the Raman Effect will be celebrated at the Indian Association for the Cultivation of Science, Calcutta.

The formal celebrations will be held on Wednesday 2 November, where the Prime Minister Shri Rajiv Gandhi will be the chief guest. He will dedicate a national monument to the memory of Professor Raman and release six volumes of the Scientific Papers of C.V. Raman and a biography. He will also present Raman centenary medals to a few distinguished scientists and former associates of Prof. Raman. The 54th Annual Meeting of the Academy will be held on 31 October and 1 November 1988 so that Fellows who attend the Annual Meeting can also take part in the celebrations on 2 November.

All Fellows and Associates attending the Annual Meeting will be paid first class railway fare from their place of residence to Calcutta and back, in case they are unable to obtain travel support from other sources. Arrangements for the stay of Fellows will be taken care of by the local organisers.

During the period of the Annual Meeting, the Editorial Boards and Sectional Committees will also meet at Calcutta.

Energy for a sustainable development

A panel discussion on energy for a sustainable development was jointly organized by the Academy and the Karnataka State Centre of the Institution of Engineers (India) at the Institution premises at Bangalore. After a brief introduction by Prof. S. Dhawan, Profs. A.K.N. Reddy, T.B. Johansson and R.H. Williams, joint authors of the volume *Energy for a sustainable world,* spoke on the theme of the panel discussion. This was followed by a general discussion. The main conclusion of the speakers was that global economic goals over the next several decades can be met with about the same level of global energy as today. This optimistic finding, in sharp contrast to conventional energy analyses that call for a doubling or tripling of global energy requirements over this period, was a result of an end-use-oriented approach to the energy problem, shifting the focus of energy supplies to the ways in which energy is used and to the exploration of more effective ways of directing energy sources to human needs.

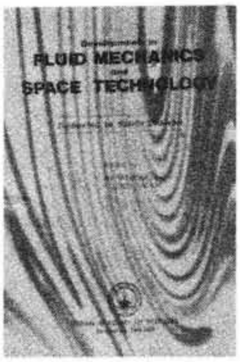
For developing countries the end-use-oriented approach can help identify ways of ensuring that energy strategies support the overall development goals. For industrialized countries, it reveals that energy is becoming less important in shaping economic growth because of on-going shifts to inherently less energy-intensive activities.

By identifying cost-effective opportunities for making more efficient use of energy, it becomes possible to avoid overdependence on the more troublesome supply options and to begin a transition to renewable energy sources. There was general agreement among the participants on the importance of adopting energy strategies that will help bring about a sustainable world.

Special Publications

In addition to the thirtyfour special publications described in earlier issues, the following volume was published in 1988.

Developments in Fluid Mechanics and Space Technology, Editors R. Narasimha and A.P.J. Abdul Kalam, Published in 1988, Price Rs.100/–, US $ 40/–, 454 pages.



The volume is dedicated to Prof. Satish Dhawan, "who founded fluid dynamics research in the country and who led the national space programme to its present state of maturity and sophistication". The volume was formally released by Prof. Obaid Siddiqi, President of the Academy, at a meeting held in the auditorium of the Raman Research Institute on 8 July 1988. The volume is in two loosely connected parts, the first a collection of research papers in fluid dynamics, chiefly on the subjects to which Prof. Dhawan contributed or in which he was keenly interested. Some of the papers were presented as invited lectures at the 1986 Asian Congress of Fluid Mechanics in Tokyo. The second part consists of 5 overview papers which highlight the advances made in space technology over the period 1972–1984, when Prof. Dhawan led the national space programme.

The contents of this volume were published in Volume 10, parts 3 and 4 of August 1987 and volume 12 Parts 1–3 of February–March 1988 of *Sadhana*.

Special issues of journals

Synthetic Organic Chemistry, Proceedings – Chemical Sciences, Vol.100, Nos 2 and 3, April 1988

Traditional synthetic organic chemistry is on the verge of a revolution. This special issue, incorporating a collection of seven overview articles and three research papers, covers areas of current interest such as the synthesis of complex natural products, chiral compounds of high enantiomeric purity, the development of a series of useful new reagents and reactions using simple starting materials, and some interesting aspects of synthetic organic chemistry like organo-lithiation and halogen metal exchange.

Physics of Defects. Bulletin of Materials Science, Vol.10, Nos 1 and 2, 1988

Although the study of defects is an old subject and materials science has always been concerned with it, it is only in the past decade that defects have come to be regarded as the key elements to characterize configurations of any ordered medium. Magnetic systems, liquid crystals, lyotropic systems, superfluids, quasi-crystals and even disordered systems like glasses have defect configurations which dominate their thermodynamics and transport behaviour as well as phase transitions.

To focus attention on such aspects of defects, a discussion meeting was organized at the Department of Physics, University of Roorkee, from 23 to 26 March 1987. The meeting was jointly sponsored by the Academy, the National Physical Laboratory and the University Grants Commission. About 30 participants from all over the country took part and the Proceedings, published in this special issue, include 15 of the talks delivered at the meeting.

Distribution of Journals

Contracts had been signed in 1984 with M/s J C Baltzer, Basel, Switzerland for the promotion and distribution of Academy journals abroad and in 1986 with M/s Allied Publishers Subscription Agency, Bangalore for their distribution in India and South Asian countries. These have now been terminated, since the circulation has shown no improvement during the last four years. From 1989, the Academy office with a new Circulation Department will directly handle this work.

Since the main consideration of the Academy is an increase in the circulation and readership of the journals, rather than an increase in income, new subscription rates have been offered to subscribers, with several incentives such as concessions for those who renew them at a time for periods up to 5 years. Individual letters have been written to over 600 foreign subscribers indicating the changes in subscription rates and the replies received so far have shown an encouraging response.

Annual Report for 1928

Annual Report for 1928 of the Indian Association for the Cultivation of Science

In the Centennial year of the birth of Professor C.V. Raman, we publish in full Part I of the Annual Report for 1928 of the Indian Association for the Cultivation of Science, which also contains the speech that Professor Raman gave at the Science Congress held at Madras in January 1929.

PART I

REPORT ON SCIENTIFIC INVESTIGATIONS

Following the precedent of earlier reports, it is proposed in the following pages to give in a form as free from technicalities as possible, a general account of the scientific results published during the year 1928 by your Honorary Secretary and the research workers under his direction.

1. A New Radiation Effect

The story of the discovery of the new effect and its fundamental significance are set out in the Presidential address given by your Honorary Secretary to the Indian Science Congress at Madras on the 2nd January, 1929. No apology is needed for including this address as a part of this annual report.

"It is the privilege of a physicist to concern himself with what may be regarded as the fundamental entities of the material universe we live in. His theories and experiments are directed towards obtaining a clearer understanding of the nature of those entities and of their relationships with each other. His results if expressed in plain language should be intelligible not only to those who profess other branches of science, but to all who take an interest in the varied phenomena of Nature. The work of the physicist has the closest possible bearing on the interpretation of facts observed in other fields of scientific knowledge. No apology is therefore needed for my decision to devote this address to an exposition of the nature and significance of a new phenomenon recently discovered in my laboratory at Calcutta which has a bearing on the fundamental problems of physics and chemistry.

Everyone of us is or should be interested in the nature of that phenomenon which we call light and which is a species of the genus radiation. Light is emitted by matter under suitable conditions of excitation. We heat an atom or excite it by electric discharge. It becomes luminous and gives off radiation. What is radiation? On this point, the physicists of the nineteenth century had come to the very definite conclusion, based on evidence which it seemed impossible could ever be shaken, that light is a kind of wave-motion travelling through space, and of the same physical nature as the electro-magnetic waves discovered by Hertz and now so familiar to all as the waves of wireless telegraphy and telephony. Remarkably enough, however, the present century has witnessed a re-opening of the question. I will not pause here to trace in detail the history of the development of what is known today as the quantum theory of radiation. It is associated with the names of three great living physicists, namely, Planck, Einstein, and Niels Bohr. It will suffice for my purpose to indicate the very definite and intelligible form it received in Bohr's well-known theory of spectra. According to Bohr, the emission of light from an atom is not a single process but takes place in two distinct stages. The first stage is the energizing of the atom, in other words its passing over from a normal or non-luminous condition into a new state of higher energy content. The second stage is the return of the atom to a condition of lower energy accompanied by the emission of light. Bohr found it necessary, in order to interpret the facts of spectroscopy, to assume that the different states of the atom are sharply differentiated from each other in their energy content. The atom therefore takes up energy or gives up energy, as the case may be, in passing from one state to another, in discrete bundles or quanta. Radiation is thus absorbed or emitted by the atom in discrete bundles of energy. It follows naturally that while travelling through space, light also remains as discrete bundles or quanta of radiation. A distinctly unitary character is thus indicated for radiation.

Further powerful support for a corpuscular idea of radiation came to hand a few years ago when Prof. A.H. Compton, now of Chicago University, discovered a remarkable phenomenon which is now known by his name as the Compton Effect, and for which he received the Nobel Prize in Physics a year ago. Briefly, what he found was this: When X-rays fall upon matter and the scattered rays are analysed by an X-ray spectroscope, the lines in the X-rays spectrum are found to be doubled. Prof. Compton gave a very simple and remarkable explanation of this fact. He regarded the incident X-rays as consisting of corpuscles which moved with the velocity of light and on hitting an electron in the scattering material dislodged it and were themselves deviated from their straight path. It is obvious that in such a process the deviated corpuscle would lose part of its energy, this being taken up by the recoiling electron. Prof. Compton's explanation of his effect is supported by the fact that the recoil of the electron is actually observed in experiment. A change in energy of the quantum is equivalent to a change in the frequency of scattered radiation, which therefore appears in the X-ray spectrum as a line in a shifted position. Measurements of the change of wavelength and of the velocity of the recoil-electron appeared strongly to support Prof. Compton's theory, and the latter has therefore gained general acceptance.

We appear thus to have reached the astonishing position that two distinct theories of light both claim our acceptance. In other words, light consists of waves expanding spherically outwards from a luminous atom into ever-increasing volumes of space, and it also consists of a corpuscle shot off in some one specific direction from the luminous atom and therefore moving along a straight line to infinity. I have often seen it suggested that there might be no real conflict between these two widely different points of view, if we regard the light corpuscle statistically. In other words, if we had a sufficiently large number of atoms giving out corpuscles, the two pictures of radiation may be statistically equivalent. So indeed they would be, if a corpuscle emitted from one atom and a corpuscle emitted from another could be regarded as equivalent. But such a conception would be totally repugnant to wave-principles. For, when we consider a luminous gas, the waves emitted by the different atoms in it would not be equivalent unless all the atoms were at the same place and emitting light-waves in identical phase. It is obviously difficult to accept the latter proposition, and in fact we may be fairly certain that it is untrue. The particular suggestion here made for securing a statistical equivalence of the wave and quantum theories of radiation seems therefore untenable. My own feeling is that it is impossible to accept the wave and quantum theories of radiation as simultaneously true if Compton's idea of a localised quantum is a correct and universal description of the process of radiation from atoms. In order to explain the familiar facts of optical interference and diffraction, we are compelled to assume that the light emitted by a luminous atom spreads out spherically with identical velocity and phase in all directions. Theoretically it is possible to analyse a spherical wave into a set of plane directed waves passing simultaneously through the centre of the sphere in all directions, *provided they are all in identical phases at the centre*. We may, of course, regard a plane wave as equivalent to a directed quantum in the sense of Compton, but as a single atom can only radiate one quantum at a time, it is impossible to explain interference if we assume the emission to consist generally of directed quanta. In Compton's own experiment, we are dealing with the secondary radiation from an atom illuminated by X-rays of wavelength much shorter than the diameter of the atom. This is a very different problem from that of an atom radiating spontaneously in all directions. In a paper appearing in the Indian Journal of Physics, I have discussed the case of Compton from what I believe to be rather a novel point of view, and shown that so far from the Compton Effect being opposed to the classical wave-principles, the latter actually indicate the existence of such an effect. On the view developed in my paper, Compton's experiment is not a disproof of the spreading wave-theory. We do not regard the beam of radiation thrown out in a straight line by a light-house and travelling for miles without appreciable spreading, as a contradiction of wave-principles, but explain it as an effect produced by the lenses and mirrors of the light-house. In an analogous way, I utilise the relation between the wavelength of the radiation and the size of the atom to explain Compton's results. The investigation shows that the classical and quantum theories of radiation are indeed statistically equivalent, but this equivalence is secured by the properties of the atom, and not by filling space with localised quanta. I will go so far as to say that in my view, it is entirely futile to regard the light-quantum as a particle having any specifiable shape, size or position.

This theoretical paper on the Compton Effect was worked out during a holiday at Waltair in October, 1927. Apart from any little intellectual satisfaction which its writing may have given me, its chief interest is that it prepared the ground for the experimental work of the following months which I shall now mention.

Eight years ago, we commenced at Calcutta a series of experimental studies on the scattering of light in transparent media of all kinds. These studies were largely inspired by a desire to understand and explain fully such natural optical phenomena as the light of the sky, the dark blue colour of the deep sea and the delicate opalescence of ice in glaciers. It soon became evident that the laboratory studies intended in the first place to reproduce these natural phenomena on a small scale would carry us some way towards a solution of such fundamental problems of physics as the constitution and structure of molecules, their number, arrangement and thermal movements in gaseous, liquid and solid media, and the nature of radiation itself. I will not fatigue you by reciting the numerous experimental and theoretical researches carried out by us on these subjects. Associated with me during these eight years were a great many young physicists from all parts of India who received their research training in my laboratory. Amongst them, I would specially mention the names of Dr. K.R. Ramanathan and of Mr. K.S. Krishnan, both by reason of their conspicuous originality in research and in view of the importance of their personal contributions to the development of the subject now under discussion. To them, and to my numerous other collaborators from Bengal and Madras and Northern India, I owe a debt of gratitude.

At a very early stage in our investigations, we came across a new and entirely unexpected phenomenon. As early as 1923, it was noticed when sunlight filtered through a violet glass passes through certain liquids and solids, *e.g.*, water or ice, the scattered rays emerging from the track of the incident beam through the substance contained certain rays not present in the incident beam. The observations were made with colour filters. A green glass was used which cut off all light if placed between the violet filter and the substance. On transferring the glass to a place between the substance and the observer's eye, the track continued to be visible though feebly. This is a clear proof of a real transformation of light from a violet into a green ray. The most careful chemical purification of the substance failed to eliminate the phenomenon. Subsequent investigations showed the same effect in a considerable number of liquids and solids, and we even attempted a spectroscopic investigation of it.

Though, from time to time, we returned to the study of this new phenomenon and published accounts of it, its real significance as a twin brother to the Compton Effect first became clear to me at the end of 1927 when I was preoccupied with the theory of the subject. I regarded the ejection of the electron in the Compton Effect as essentially a fluctuation of the atom of the same kind as would be induced by heating the atom to a sufficiently high temperature, and the so-called directed quantum of Compton as merely an unsymmetrical emission of radiation from the atom which occurs at the same time as the fluctuation in its electrical state. The conception of fluctuations is a very familiar one in optical and kinetic theory, and in fact all our experimental results in the field of light-scattering had been interpreted with its aid. There was, therefore, every reason to expect that radiations of altered wavelength corresponding to fluctuations in state of the scattering molecules should be observed also in the case of ordinary light.

The idea was energetically taken up and the experiments showed it to be completely correct. It became clear that we had here a new radiation effect far more general and universal in its character than the Compton Effect, and of which the latter could be regarded as a special case. The ejection of an electron is a very violent type of fluctuation. There are numerous other comparatively mild types of fluctuation possible in the electrical state of atoms and molecules. Such fluctuations correspond to relatively small changes in the energy-level of the atomic system in the sense of Bohr. If a change of energy-level is produced by the incident radiation and is simultaneous with it, the quantum of radiation emitted under these conditions may be greater or smaller as the case may be than the quantum of incident radiation. We may represent this change as a chemical reversible reaction.

Molecule + Radiation ⇄ Molecule* + Radiation

$$E + h\nu \rightleftarrows E^* + h\nu^*$$

If the reaction proceeds in the direction of the upper arrow, we have a diminution in frequency of the radiation, and if in the direction of the lower arrow, we have an increase of frequency. The relative importance of the two types of reaction would obviously be determined by the law of mass-action, that is to say, upon the populations of the normal and excited states of the molecules present in the irradiated substance. In ordinary cases, the presence of excited states is determined by temperature. Other causes of excitation of molecules if present must also be taken into account.

Since atomic and molecular systems have many possible energy-levels as shown by the facts of spectroscopy, we see in the foregoing chemical equation the possibility of observing a great many new lines in the spectrum of the scattered radiation.

The most convenient way of studying the effect is by using the intense monochromatic radiation of the mercury arc and to condense its light into the substance, or better, actually to bring the arc into close proximity with the substance as in the well-known work of R.W. Wood on resonance spectra. The spectrum of the scattered radiation is then readily photographed and shows a multitude of new lines, bands and in addition continuous radiation. The relation between the frequencies of the incident and scattered radiations will be readily noticed from the equation written above symbolically. The difference between the incident and scattered quanta is equal to the quantum of absorption or emission as the case may be of the molecules. The characteristic frequency of the molecule is, therefore, subtracted from or added to the frequency of the incident radiation to give that of the scattered light.

In one sense, this combination of the incident frequency with the frequency of the molecule is an analogue of the classical phenomena of Tartini's Tones which we are familiar with in acoustical theory, and which are explained in terms of the forced vibrations of a non-harmonic oscillator. This analogy may no doubt be used to find the intensity of the modified radiations approximately, by applying the correspondence principle to a non-harmonic molecular model of suitable type. The difference between this classical analogue and the actually observed optical effect is in the extraordinary disproportion between the intensity of the lines corresponding to the differential and summational tones respectively, which is far greater than in the acoustical analogies.

An extremely interesting and fundamental point regarding the new type of secondary radiation is that, in general, it is strongly polarised. In this respect, the phenomenon is analogous to the experimentally known polarisation of the Compton type of X-ray scattering. We notice, however, that the different lines corresponding to different molecular frequencies are polarised to very different extents. It may be presumed that this is due to the molecular oscillators involved not possessing spherical symmetry. Whether this explanation is sufficient or not remains to be tested by computation and comparison with observation.

We may here pause a little to consider more closely the real significance of our phenomenon. Some, no doubt, will claim to see in it a further confirmation of the quantum theory of radiation. My own view, however, is that there is nothing in the effect that in any way contradicts the wave principles. The new fact that emerges is that we can cut up or add to the quantum of energy to any arbitrary extent, if we accept the idea of a real, corporeal existence for it. We may of course, avoid this inference by assuming that the incident quantum in some way disappears on collision with the molecule and that a new quantum of smaller or larger energy arises from the combination. But the observed fact of the strong polarisation of the lines is unfavourable to the latter idea.

I shall now pass on to consider some applications of the new effect. Its potential value perhaps is greatest in the field of chemistry. The method of investigation affords us an extraordinarily easy and convenient process of mapping the infrared spectra of chemical compounds. The geometry of the chemical molecule and the forces of chemical affinity determine the frequencies of molecular vibrations. In many cases, they lie in the far infrared, a region of the spectrum which has hitherto been difficultly accessible to observation. The study of light-scattering enables us, as it were, to photograph the whole infrared spectrum with the same facility and ease as the visible and ultraviolet spectra. The determination of the fundamental vibration-frequencies of the chemical molecule, their relative improtance as gauged by the intensities of the lines, and even more, their peculiar polarisation characters promise to take us deep into the fundamental problems of chemistry. As an illustration, I will mention a recent paper by Daure in the *Comptes Rendus* of the French Academy. Daure investigated the spectra of the chlorides of carbon, silicon, titanium, arsenic, lead, antimony and bismuth by this method. The investigation revealed hitherto unknown spectra in the far-infrared for each of the compounds studied, exhibiting remarkable analogies and differences amongst each other in the position, intensity and polarisation of the lines.

In organic chemistry also, the method opens up an illimitable field of research. Numerous lines appear whose positions in many cases are accurately measurable, and are influenced notably by changes in chemical constitution. A very surprising feature is the extreme sharpness of some of the lines. The frequencies of the vibration of the carbon-carbon bond in benzene can be determined, for example, with extraordinary precision unapproachable by other methods. It is precisely this accuracy of measurement and the rich and varied mass of data obtainable that indicate for this method a real future.

The study of the influence of changes of temperature and pressure, and of a change of physical state on the intensity, positions and widths of the spectral lines promises to furnish information of value in the field of molecular physics. Already in our earliest observations it was noticed that the spectral lines obtained with ice are sharper and somewhat displaced in position relatively to the broad bands found with liquid water. The sharpness of the lines observed with transparent crystals appears to be a general feature. As an example I may mention the case of selenite in which Mr. Krishnan found that the water of crystallisation also gave well-defined lines instead of the bands observed with water.

Preliminary studies have shown that it is perfectly practicable to photograph the lines in the spectra of vapours. Hence it will be possible in many cases to investigate the changes in molecular spectra in the passage from vapour to liquid as well as those in the passage from liquid to solid. In the change from vapour to liquid, we have a partial destruction of the freedom of rotation of the molecules. Such observations as we have made seem to indicate that exchanges of energy between the incident quantum and the molecule can also occur with respect to the rotational states of the molecule. The optical anisotropy of the molecule appears to be involved in the possibility of such induced molecular rotation. Whether the removal of restriction on rotational freedom, when the molecule passes from liquid to vapour, results in a fuller development of such rotational spectra remains to be investigated.

At low temperatures, many liquids as is known refuse to crystallise, become highly viscous and ultimately are transformed into glasses. Glycerine is a typical example of such a liquid. Mr. Venkateswaran has observed in it a remarkable development of a continuous spectrum whose intensity falls with rise of temperature or by dilution with water. The precise origin of this phenomenon and the existence of similar effects at low temperatures in the case of other viscous liquids remain to be studied. The problem of the amorphous solid condition is related to this. Already Pringsheim has noted that fused quartz, unlike the crystalline substance, does not show any lines in the scattered spectrum. The explanation of this must be that the lines have become very broad and diffuse.

2. X-ray Diffraction in Liquids

A detailed account was given in the last year's report of the researches on the nature of liquids using the powerful method of X-ray analysis, carried out by Dr. C.M. Sogani in this laboratory. After finishing another short investigation on a new critical absorption method for observing the Compton Effect, Dr. Sogani rejoined his duties at Benares, and the work on X-ray diffraction was taken up at this stage by Mr. P. Krishnamurti, and laterly by others. The liquid state, as everyone knows, ranks as much in importance as the crystalline state of matter, and X-rays have been largely responsible for our present understanding of the regular arrangement of the molecules and atoms composing the crystal. It is quite evident, therefore, that the X-ray method should ultimately provide a complete solution regarding the structure of liquids and amorphous bodies, and our knowledge concerning them will progress with our ability to interpret the diffraction phenomena, especially in relation to the known effects in crystalline solids. The X-ray method, as has been recently pointed out by Carl Drucker and as experimentally demonstrated in this laboratory, is capable of application not only in elucidating the fine structure of liquids but also in solving the various problems confronting the physical and organic chemist. What happens when, for example, a lump of sugar dissolves in water? What is the difference between ordinary and colloidal solutions, electrolytes and non-electrolytes, sols and gels? What is the exact significance of the term 'Molecular Association' of liquids? Is the shape of the molecule in a liquid in conformity with the ideas of the organic chemist, developed from laborious studies of their reactions? These are some of the questions which we have attempted to solve with considerable success by means of the X-ray method in our laboratories.

The X-ray technique for the examination of liquids was quite similar to that used by Dr. Sogani in the previous year. An improvement was effected, however, by substituting a high-tension oil-immersed transformer for the induction coil and interrupter. By this means, a stronger and steadier beam of X-rays was obtained, and a good photographic record of the diffraction pattern could be obtained in 1–2 hours, thus enabling a large variety of liquids to be examined. The copper radiation (Ka = 1.51 A.U.) was employed since it was contaminated with very little white radiation, and yet did not undergo excessive absorption by the liquids studied. Another improvement consisted in the elimination of photographic halation in the plates due to the primary beam, by interposing a small lead disc just in front of the plate. This enabled a number of new and interesting effects present at small angles to the central beam to be observed.

A complete study of mono and disubstituted benzene derivatives showed that as a general rule, the ortho and meta compounds exhibited two rings, whereas the para ones gave rise to one broad ring resembling more the patterns for the monosubstituted derivatives. The relative intensities of the inner and outer rings in the ortho compounds were found to depend on the nature of the substituents, heavier groups tending to strengthen the outer ring. Further, as the size of the substituent group increased, the outer ring decreased in size slowly, while the inner did so rapidly, the former approaching the size for a long-chain aliphatic derivative. Measurement of the spacings of the rings using the well-known Bragg formula showed that the values for the outer rings ranged from 3.5-4.0 A.U. for the various compounds, and were interpreted as due to the approximate regularity of the spacings perpendicular to the plane of the benzene ring (the thickness of the molecule), while the spacings of the inner haloes were attributed to the regularity of arrangement in the plane of the ring. These values are moreover in agreement with the dimensions of the molecule deduced from the solid state.

The difference between a long-chain compound and an isomeric closed-chain one produced from it by re-arrangement was also investigated. Geraniol and terpineol as representatives of the two types gave different patterns which showed (1) the smaller length of the latter molecule, (2) its greater symmetry, as could be judged from the larger size of the inner ring and the contraction and sharpness of the outer ring in the case of terpineol.

As mentioned previously, the cutting out of the halation produced by the central beam enabled fainter rings at small angles to be recorded and observed. Ethyl alcohol, acetic acid, trimethyl carbinol and phenol showed this inner ring, of which the first three were observed by Stewart and explained by him as due to the bi-molecular spacing, *i.e.*, due to two molecules joined together end to end as in surface films of long-chain fatty acids. These faint inner rings were observed also in several other aliphatic and aromatic compounds, *viz.*, the phenols, amines, aldehydes and nitriles, especially in those liquids that showed a large association factor and an abnormally low value for the Ramsay-Shields constant. While studying the relation between the intensity of the inner rings and the degree of association of these liquids, a frequent discrepancy was observed in the case of substances like diphenylamine or the higher fatty acids in the liquid state. These showed higher values for the Ramsay-Shields constant K, indicating dissociation, whereas from analogy with other liquids containing polar groups one would expect them to be associated and hence to show low values for the constant. A consideration of their shapes at once showed that they were quite unsymmetrical. An approximate parallel arrangement of the molecules in the fatty acids was indicated by the X-ray patterns, since the haloes attained a constant size when the chain consisted of more than five carbon atoms. The orientation of the molecules at the surface ought to bring together a greater number of molecules per unit area than the average value calculated from $(M\mu)^{\frac{1}{3}}$ as in the Ramsay-Shields formula. Since this arrangement of the molecules varies from liquid to liquid, a method for estimating it was searched for, and ultimately found in the X-ray pattern itself. As the spacing of the prominent ring corresponds to the most frequent distance between neighbouring molecules, this value when substituted in the Ramsay-Shields formula ought to give correct values for the constant. This was done in the case of several liquids, and by this means several anomalous values have been rectified, notably those of diphenylamine and of the higher fatty acids.

Influence of Temperature on X-ray Liquid Haloes

A brief account of the degeneration of the X-ray haloes at high temperatures was given in the report for last year. The theory put forward by your honorary Secretary and Dr. Ramanathan in 1923, predicted three main effects on the liquid haloes with increasing temperature, (1) a notable contraction of the ring, (2) broadening of the ring and diffuseness at the edges, (3) a large amount of internal scattering. All the three effects were actually observed by Mr. S.S. Ramasubramanian with pure liquids like cyclohexane, pentane, glycerine and also in the case of a synthetic resin. The first effect is due to thermal expansion of the liquid, since the distance between the molecules is increased thereby. The second effect is due to increased displacement of the molecules from their mean positions. The third effect arises from the local fluctuations of density of scattering electrons arising from the varying positions and orientations of the molecules within the liquid. In the case of spherical or nearly spherical molecules, this effect is limited, whereas in the case of long-chain compounds it reaches its maximum.

X-ray Diffraction in Solutions

The physico-chemical nature of solutions whether of electrolytes, non-electrolytes or colloids is quite capable of elucidation by the X-ray method. As the previous experiments of Wyckoff proved inadequate, the problem was taken up by Mr. Krishnamurti, and results of great importance have been obtained in this field. It is a well-known fact that in a dilute solution containing a non-volatile solute, like cane-sugar in water, the molecules are distributed at random in the solution like those of a gas. Van't Hoff first showed the analogy between the osmotic pressure of a dilute solution and the gaseous pressure which it would exert if it existed in the form of a gas in the volume occupied by the solution. The X-ray diffraction patterns of aqueous solutions of cane-sugar, levulose and glucose give us a striking experimental proof of Van't Hoff's hypothesis. In a dilute solution of cane-sugar, for example, it was found that in addition to the ring for water, there appeared a strong scattering surrounding the central beam and having the characteristic appearance of a corona. The intensity of the difraction disk increased with an increase in concentration of the solution until it contained almost equal quantities of solvent and solute. A similar case is met with when a source of light is viewed through a plate of glass covered with a layer of dust. The coronae observed in both these cases is due to diffraction by randomly distributed particles. The phases of the waves starting from the particles are entirely uncorrelated with the result that no interference is possible, and the total intensity is given by adding up the effects due to all the particles. Hence, we find in sugar solutions, upto a conc. of about 1 : 1 by weight that the intensity of the corona increases with the concentration.

A further interesting point arises when we consider the extents of the coronae in solutions of different substances. At the same concentration by weight levulose and glucose ($C_6H_{12}O_6$) gave coronae of about the same size, while in cane-sugar ($C_{12}H_{22}O_{11}$) solution it was considerably smaller in size but more intense. When the spacing corresponding to the outer edges of the coronae were calculated by applying the Bragg equation, it was found that the spacing thus obtained was approximately equal to the size of the dissolved molecule, or $(M/d)^{\frac{1}{3}}$ where M is the mass and d the density of the substance. Hence, the bigger the molecule, the larger the spacing and hence the smaller the extent of the corona.

At concentrations higher than 1 : 1, a sudden diminution of intensity occurred at small angles, and a ring was produced. This can be readily understood since the molecules could not then be expected to be distributed at random as in a dilute solution. They possess an approximate special arrangement, and hence the phases of the scattered waves are not uncorrelated, resulting in destructive interference and leading to the production of a maximum at larger angles. The patterns for the most concentrated solutions resembled those given by the pure liquids or by the powdered solids.

Ammonium nitrate was the one case of an electrolyte which was studied. Dilute solutions gave the water ring and a general scattering within the ring. This can be readily understood since in a dilute solution the substance is ionised and the ions being of small size, the scattering is distributed over a larger area. In the more concentrated solutions examined (3:1), a very definite maximum was observed within the water ring, which became more diffuse at 2:1 and disappeared as a general scattering at 1:1 dilution. This showed conclusively that the molecules or ions in a concentrated solution of electrolyte possessed some arrangement capable of being detected by X-rays.

3. Optical Properties of Molecules

Mr. Ramchandra Rao continued his studies on light-scattering in liquids at high temperatures, and has found that the factor of depolarisation for the transversely scattered light diminishes with temperature, at first slowly and later rapidly, until the fall becomes less rapid as the critical temperature is approached, and that the optical anisotropy of the molecules in the liquid apparently increases with temperature and tends to attain the value in vapour. These results are quite concordant with the new theory of light-scattering put forward by the present writer with Mr. Krishnan, an account of which was given in last year's report. In Ramanathan's modified theory, the distribution of molecules surrounding the one in consideration was assumed to be spherically symmetrical. When, however, molecules are highly asymmetric in shape and are densely packed, the distribution of molecules around any one in consideration is highly asymmetric and consequently the polarisation field acting on the molecule is anisotropic. When this anisotropy of polarisation field is taken into consideration, as has been done in the new theory by the present writer with Mr. Krishnan, the large diminution in the optical anisotropy of the molecules of a substance, as it passes from vapour to the liquid state, is easily explained. With the rise of temperature of the liquid, the freedom of molecules increases and consequently the anisotropy of the polarising field diminishes, thus giving a greater value for the optical anisotropy of the molecules.

It has been mentioned in the last year's report that Mr. Ramkrishna Rao studied scattering of light in 63 vapours and 7 gases. He observed that generally the optical anisotropy of molecules in the vapour state is greater than that in the liquid state but for formic and acetic acids, the anisotropy of the molecules in the liquid state is greater than that in the vapour state. Mr. Ramchandra Rao has carried out investigations in order to find an explanation for this peculiar behaviour of the formic and acetic acid molecules. He finds that for polar molecules such as fatty acids, nitrobenzene, aniline, etc., the optical anisotropy in the liquid state at first diminishes with rise of temperature and then rises as the temperature is further increased. This peculiar behaviour in the case of polar molecules is attributed to association of molecules in the liquid state.

According to classical theory of scattering, light scattered in a direction perpendicular to the incident beam by an isotropic molecule should be completely polarised. The depolarisation of this transversely scattered light is produced by the optical anisotropy of the scattering molecules. It is well-known that all substances including rare gases produce this depolarisation of transversely scattered light, and hence the molecules are anisotropic. Sir J.J. Thomson explained the molecular anisotropy assuming that it is dependent on the number of electronic shells in the molecule. But recent experiments with many organic liquids show that his theory cannot explain the facts satisfactorily. The present writer suggested that the total polarisation induced in a molecule is the sum of the polarisation of the atoms constituting it and that the doublets induced in the atoms due to the incident light influence each other, this mutual influence for incident light having its electric vector along the line joining the atoms being different from that for incident light vector perpendicular to this line. On these lines Ramanathan and later on Havelock calculated the anisotropy of various molecules and found some agreement with scattering data available at that time. Mr. Ramkrishna Rao after determining accurately the factor of depolarisation of 63 vapours and 7 gases found that some of the values taken by Ramanathan and Havelock were wrong to the extent of 25 to 50%. Mr. Rao in a paper on anisotropy of atoms and molecules has first calculated with the help of his own data on light-scattering, the interatomic distance in molecules from the expressions arrived at by Ramanathan, and has compared them with those obtained from X-ray data. He finds large discrepancies between the interatomic distances obtained from optical data and those obtained from X-ray measurements. He accounts for this discrepancy by putting forward the idea that the atoms constituting the molecules are anisotropic. Taking the interatomic distance from X-ray data and from known values of refractive index and factor of depolarisation, he has been able to calculate the anisotropy of the atoms of a few gases. He has also calculated the anistropy of ions and has come to the conclusion that rare gas atoms are less anisotropic than the rare-gas-like ion such as chlorine, sulphur, oxygen and such other ions, and that heavier atoms show less anisotropy than lighter ones.

Brewster observed that when an optically isotropic substance is subjected to nonhomogeneous stresses it becomes birefringent. Neumann tried to explain this phenomenon but the theory put forward by him does not satisfactorily explain the observed facts. Taking the molecular constitution of matter into consideration, Mr. Kedareswar Banerji has developed a theory for calculating stress-optic co-efficients of some ionic crystals and amorphous solids. He has first calculated the effect on the polarisability of a molecule, of the polarisation field due to the neighbouring molecules for light vector along and perpendicular to the direction of the stress. Taking into consideration this point alone he finds that the calculated values of double refraction do not agree with those actually observed in the case of ionic crystals, and quite contrary to the facts the calculation gives no double refraction for amorphous solids. Hence some other effects produced on the molecules by the stresses have to be taken into consideration. When a substance is subjected to a uniform hydrostatic pressure, its refractive index undergoes changes due to two causes, (1) due to increase in the number of molecules per unit volume known as the Lorentz factor, and (2) due to change of polarisabilities of the or ions due to proximity of molecules or ions. Taking also this print into consideration and calculating the change in the refractive index due to both the causes Mr. Banerji has been able to calculate the double refraction produced by unit pressure in a few ionic crystals and amorphous solids and the results are in good agreement with experimental values.

4. Electrical and Magnetic Properties of Molecules

An account has been given in the last year's report of a discussion by the present writer with Mr. Krishnan of the Kerr effect in liquids and gases, in terms of refractive index, factor of depolarisation of transversely scattered light and the permanent electric moment of the molecules. When these optical constants of a substance are known, the permanent electric moment of its molecules can be easily calculated and when the moment can be found out by any other method its direction can be fixed in the molecule. Mr. Sirkar has determined the permanent electric moments of the molecules of methylchloride, ethylchloride and chloroform by measuring the dielectric constant of the vapours at different temperatures by heterodyne null method and has found that the value of permanent moment of the methylchloride molecule obtained from optical data, assuming its direction to coincide with the A axis of the optical anisotropy exactly coincides with that obtained by the electrical method. For ethylchloride, the value of permanent moment obtained from optical data with the same assumptions differs from that obtained by electrical method, which shows that the direction of permanent moment does not coincide with an axis of the optical anisotropy of the molecule.

In the papers by the present writer with Mr. Krishnan quoted in the last paragraph, it has been shown that for liquids of which the molecules are polar, the contribution to the Kerr effect due to the permanent electric moment is predominant and is sometimes oppotsite in sign to the contribution due to the induced moment. In an oscillating field of very high frequency the dipoles do not find time to orientate themselves, and hence cannot contribute to the Kerr effect, so that it is expected that for such liquids the Kerr effect will diminish to a very small value and have its sign reversed when the frequency of the oscillating field applied is increased. It has been observed by the present writer with Mr. S.C. Sirkar that this actually happens in the case of octyl and higher alcohols when a Kerr cell containing the liquid is connected parallel to a radio frequency oscillating circuit when the frequency exceeds 3×10^6.

In the last year's report[*] an account has been given of Mr. Vaidyanathan's studies on magnetic properties of vapours. During the year under consideration, Mr. Vaidyanathan measured the magnetic susceptibilities of a few typical ozonides using a Curie balance with necessary modifications. The ozonides were all found to be diamagnetic. From this two most reliable measurements, *e.g.*, those for phenanthrene and naphthalene diozonide, he calculated the susceptibility of O_3 molecule by subtracting the molecular susceptibility of the mother substances on the basis of Pascal's additive law. The value thus obtained was found to be in the proximity of -25×10^{-6} per gram molecule. A structure of the molecule has been postulated and possible electron arrangements have been discussed. Mr. Vaidyanathan has also studied the magnetic properties of ozone gas and finds that the gas is diamagnetic.

Ethylene vapour was thought to be feebly paramagnetic. Mr. Vaidyanathan has measured its magnetic susceptibility and has found that ethylene vapour is diamagnetic and has a molecular susceptibility equal to that of sulphur which has the same number of electrons as ethylene. He has also discussed the structure of the molecule from magnetic and chemical standpoints.

With his sensitive apparatus Mr. Vaidyanathan has measured the magnetic susceptibility of carbon dioxide, argon and nitrogen at low pressures and finds that there is a strict proportionality between pressure and volume susceptibility.

5. Other Investigations

During the year under consideration Dr. L.A. Ramdas of the Meteorological department studied the spectrum of potassium excited while it burns spontaneously in an atmosphere of chlorine. The arc lines, an intense broad band in the red region due to molecules of potassium and a few feeble lines which appear to be the enhanced lines, are emitted. The explanation of these lines has been discussed by him.

Dr. Ganesan examined the fine structure of five ultraviolet absorption bands of oxygen.

When white of the egg is rubbed between the plane surfaces of two glass plates, small circular air bubbles are formed in the liquid between the plates. This thin film is called a mixed plate. It exhibits interesting colour effects when white light falls on it. Finding the existing theories inadequate to explain all the observed phenomena, the present writer with Mr. B.N. Banerji gave a full explanation of the phenomena treating the problem as due to laminar diffraction at the rounded edges of the air bubbles. On examining such a mixed plate under a high power microscope Mr. Ramkrishna Rao has found that the diffracting edges appear double on both sides and that the boundaries exhibit colour effects similar to those exhibited by striae in mica. On studying the wave front emerging from the air bubble, Mr. Rao has been able to explain all the phenomena observed.

The present writer with Dr. P.N. Ghosh investigated the colours of light diffracted through small angles by striae in mica. Accounts of detailed investigations together with mathematical discussions were given by Ghosh and by Sur. Mr. Ramkrishna Rao has followed up the work and has studied the colour, intensity and polarisation effects of the light diffracted at large angles by these laminar boundaries. The investigation reveals certain analogies between the distribution of intensity and polarisation of light diffracted by laminar boundaries and the corresponding phenomena observed with sharp metallic edges observed by Gouy, Wien and others. Mr. Rao has also studied laminar diffraction effects produced by edges of mica laminae having a thickness of the order of wavelength of light. A theory of diffraction by a transparent lamina was given by the present writer with Mr. Ramkrishna Rao and Mr. Rao has found that, as expected from this theory, edges of thin transparent mica laminae exhibit intensity, colour and polarisation effects exactly similar to those exhibited by sharp metallic edges.

A new method for studying the Compton effect was devised by the present writer with Mr. Sogani during the year under consideration. The scattered X-rays were passed through an absorber and recorded on a photographic plate, the wavelength of the X-rays and the particular absorber being chosen so that the wavelength of the unmodified ray was slightly smaller and the wavelength of the Compton ray, at some convenient angle of scattering, slightly greater than the critical *K*-absorption limit of the absorber. The density of the photographic impression changed abruptly as the angle of scattering varied in the neighbourhood of the angle at which the wavelength of the Compton ray was equal to that of the *K*-absorption limit. The proportion of modified to unmodified scattered radiation was also investigated and the known features of the Compton effect were unambiguously indicated.

Mr. Manindranath Mitra has published in our Journal some photographs of coronas produced by water droplets in monochromatic light. These coronas differ very widely from the simple type of Fraunhofer diffraction pattern due to an opaque spherical obstacle.

Mr. B.N. Sreenivasiah has analysed the crystal structure of paranitrotoluene and has found that it belongs to the space group Q with 8 molecules per cell, the sides of the unit cell being given by $a = 10.1$ A.U., $b = 11.18$ A.U., and $c + 12.3$ A.U.

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Obituaries

Ponnambalam Kumaraswamy was born on 4 October 1930. After his preliminary schooling, he took his B.E. degree in Civil Engineering from the Madras University in 1951. He joined the Irrigation Research Station in Poondi soon after and was appointed Assistant Engineer and Assistant Research Officer in Hydraulics in 1951, in which capacity he worked till 1957. From 1957-65, he served in various capacities in different engineering departments in Tamil Nadu, as civil engineer in charge of irrigation, and construction of canals, storage reservoirs and harbour breakwaters. He rejoined the Poondi Irrigation Research Station as Research Engineer in 1965 and worked there till 1970, when he was appointed Director of the Station. He worked as Homi Bhabha Fellow in TIFR in 1967-68 on the design of analog computer for simulating ground water aquifers and at the Massachusetts Institute of Technology in 1968-69, as Research Fellow in the Centre for Advanced Engineering Study on computer systems.

He joined the Kerala Water Resources Development Management Centre, Calicut in 1972 as Executive Director and served in that capacity for a few years. He was elected a Fellow of the Academy in 1972.

His main areas of specialization were hydraulics, hydrology and computer simulation. His work on ground water models and their computer simulation and on pump-test methodology as well as his accurate prediction of ground water behaviour is well known.

He passed away at Trivandrum on 9 March 1988.

Yerramilli Sreerama Murty was born on 15 May 1925 in a middle class family in Andhra Pradesh. He received his early education in Rajahmundry and Kakinada and obtained his Master's degree in Botany from the Banaras Hindu University in 1947. He joined Meerut College as a lecturer in Botany in 1948, where he helped to organize a centre of teaching and research in botany. Working on the morphology of the flower of piperales he obtained the Ph.D. degree of the Agra University in 1956. In 1961 he worked for a year as a research fellow in Chicago on the organography and floral anatomy of *Erica* and the genetic and nutritional aspects of *Fusarium*.

He was promoted as Head of the Botany Department in 1965 but left the college in 1969 to join the Meerut University and the newly started Botany Department there. In 1972 he took over as Professor of Botany and Head of the Department of Botany and worked there till he retired from service in 1985.

He was elected a Fellow of the Academy in 1979. He was one of the two Editors of the Journal of Indian Botanical Society from 1968 and rendered valuable service as its General Secretary for 16 years. He organized the first of the Annual Botanical Conferences held at Meerut in December 1978. He was also a member of the Indian Society of Taxonomists.

He specialized in morphology, ultrastructure and taxonomy, his contributions to the morphology of a number of angiosperm families being outstanding. His work on the floral anatomy of the piperales and of the tricales with Professor Palser at Chicago are worthy of special mention.

He passed away at Meerut on 21 February 1988. He leaves behind his wife, four daughters and three sons.

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