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Current Topics

Chemistry: Opportunities & Needs

THE National Academy of Sciences – National Research Council of USA appointed, in 1964, a committee of distinguished scientists under the chairmanship of Dr Frank H. Westheimer, Loeb Professor of Chemistry, Harvard University, to survey the state of chemistry in USA, analyse the potentialities and fiscal needs for growth, and to recommend necessary measures to develop such potentialities to maintain USA at the leading position in world chemistry. The report*, though of immediate concern to USA, provides an overall perspective on research needs and opportunities in chemistry, and should be of considerable interest to educationists, research workers and planners in all countries, including India.

A survey of chemical research in India was undertaken in 1964 by the Chemical Research Committee of the Council of Scientific & Industrial Research (CSIR) at the suggestion of Dr S. Husain Zaheer to indicate the needs of chemical research and the directions of future developments. It may not be out of place to discuss some of the findings and recommendations of the Westheimer Committee in so far as they are relevant to the situation obtaining at present in India.

Developments in basic research in chemistry in USA should be viewed from the background of a highly developed and industrialized country which is fully aware of the importance of basic research. The picture is different in India. As has been pointed out in a recent survey† of scientific research in Indian universities, prior to 1947 "science and technology were introduced in India in a limited way, more as disciplines rather than as a new method and philosophy of enquiry, without any broad-based movement outside the university to give it proper direction as was the case in England". It would be of interest to analyse the socio-economic factors which are controlling the creative activity in science and technology in India today.

The following criteria have been employed in assessing the quality of work done in USA and other advanced countries: number of Nobel Laureates produced; number of papers in chemistry per annum; number of citations in non-American periodicals of work done in USA; flow of scientists; and advanced instrumentation in chemical research. During 1954-64, USA produced 4 Nobel Laureates. There is a continuous flow of scientists into USA from other countries, and the number of publications from USA in 1964 was greater than that from any other country. A survey of chemical research in India by Palit and Ghosh[‡], based on Current chemical papers (London) in 1964, showed that papers by Indian research workers constitute about 5 per cent of the world total. The distribution of papers subject-wise follows closely the international trend, but many modern topics are not covered in Indian work. Thus while we need not be unduly concerned about the small percentage of research papers, we must seriously try to improve the quality of our research work. Out of a total of 3178 citations in two British journals examined in the above report, 1175 were to US chemical publications. A random sampling of the number of citations of Indian work in papers by non-Indians in journals related to physical chemistry was made by the reviewer and it was found that out of 4876 citations in 8 foreign periodicals there were only 59 references to work done in India. Papers from India on physical chemistry constitute about 4 per cent of the total number published¶ and the low percentage of citations indicates a relatively poor standard of the work carried out in India.

According to the Westheimer Committee, the use of modern electronic instruments and computers has been one of the main reasons why countries like USA and UK are able to carry out research of a high standard. The use rate of instruments, such as infrared, ultraviolet, NMR, ESR and mass spectrophotometers, vapour phase chromatographic equipment, automatic amino acid analyser, etc., in USA is comparable to that in UK, Germany and Japan. There is little point in collecting similar data for India as we possess a very small number of these instruments. However, it would be of interest to find out for how many working hours some of these instruments available in research establishments in the country are put to use. In USA 10 per cent of the reported instruments in use involved 'home-made' systems. It may also be mentioned that in India, on the other hand, the general attitude is to regard the time and money spent on such developments as waste. In order to encourage the development of instrumentation in India, projects involving design and fabrication of instruments should receive greater weightage and should be viewed with favour. Also, it would be worth while to insist on students working for doctorate degree taking courses in electronic instrumentation.

^{*}Chemistry: Opportunities and needs, Publication No. 1292 of the National Academy of Sciences – National Research Council (Printing & Publishing Office, NAS-NRC, Washington DC), 1965. Pp. 222. Price \$ 5.00.

Scientific research in Indian universities, Survey Report No. 6 (Survey & Planning of Scientific Research Unit, CSIR, New Delhi), 1965.

[‡]PALIT, S. R. & GHOSH, S., J. sci. industr. Res., **24** (1965), 607.

BHATTACHARYYA, K., Documentation periodicals – Coverage, arrangement, scatter, seepage, compilation: DRTC Seminar 1 (Documentation Research & Training Centre, Bangalore), 1963, 53.

The type of education imparted in chemistry is an important factor in equipping the student with modern concepts of the subject. In USA two different approaches to the teaching of chemistry are being tried at the high school level, namely the Chemical Educational Material Study (CEMS) and the Chemical Bond Approach (CBA), with encouraging results. Teaching of chemistry in India follows the age old historical (rather than logical) approach, both at the high school and college levels, the main objective being to prepare the student for the examination; and success in the examination depends not so much on understanding as on cramming. Only a few new institutions in India are making efforts to modernize chemical education using the approaches mentioned above. and the Summer Institutes in Chemistry have helped. But, by and large, the method of teaching followed as well as the facilities available for practical courses are outdated and below standard. One of the undergraduate experiments in physical chemistry in USA is the spectroscopic analysis of the fluorescence of iodine vapour and the calculation of energy levels. Can we in India think of such practical exercises even at the post-graduate levels ?

Basic research in chemistry has played an important role in the development of agriculture, medicine, national defence, technology and in particular of chemical industry in USA. The particular of chemical industry in industry absorbs 38 per cent of the new Ph.D.'s and the expenditure on research and development in 1963 was \$ 900 millions. However, chemical industry contributes only 5 per cent of the university research expenditure. Basic research in chemistry is now mainly dependent on federal support; nevertheless, federal expenditure on basic chemical research is only 3.7 per cent of the total investment. The Westheimer Committee has, therefore, recommended an expanded support of basic research in chemistry in universities at an annual rate of 20 per cent for the next three or four years and at an annual rate of 15 per cent thereafter.

A survey* recently carried out shows that industries in India are employing an increasingly larger number of scientists, but personnel engaged in research and development constitute only 4.8 per cent of the total employed. In general, because of a limited market, Indian industry has not been keen to develop new products or improve their products through research. Exact details of expenditure on basic research in chemistry in India are not available. However, some details of CSIR grants to research projects in universities are available. Out of a total grant of Rs 8.8 million, research projects in chemistry get the maximum share (45 per cent) followed by physics and biology (22 and 11 per cent respectively). What is needed now is an improvement in the quality of research along with an integration of scientific research with the total economic development of the country. This evidently will require an increase in the budgetary expenditure in scientific research and a stricter screening of research proposals.

How a research proposal should be evaluated and what principles should guide the government's support to science in universities have been considered in the Westheimer Report. The criteria proposed should be of interest to us. One of the criteria employed currently is ' proposal pressure ' --the number and size of the research proposals. Other criteria suggested are termed 'internal' and external' criteria. The first takes into consideration whether the field is ready for exploitation as also the competence of the scientists and the second the technological, scientific and social merits of the proposal. A research proposal has to be judged individually on the basis of the above criteria. Two points are of particular interest to India. First, it will be of advantage to work on topics of special interest to the country, even though they may not be of immediate practical value. Secondly, obsolescence in all forms has to be fought. As is common knowledge, proposal sanction has often been influenced by the personality factor. It is hoped that for the purpose of improving the quality of work, the proposals will be more strictly scrutinized; a proposal that is just a repetition of an old theme should be dropped so that a new one may take its place and an already established lead in any field is consolidated.

The Westheimer Committee maintains that in the planning of chemical research, emphasis should be on basic research, and the Committee's recommendations in this regard are of general interest to all organizations financing research. The Committee has recommended that: (i) funding agencies should allocate more funds for research in chemistry and specifically to younger scientists; (ii) more funds should be provided for procuring advanced instruments for teaching in universities; (iii) more government support should be given to basic research in universities; (iv) scientists themselves should organize joint projects so as to prevent fragmentation of research grants; (v) chemical education should be modernized, the system of post-doctoral fellowships appraised and more computer facilities be arranged in universities; and (vi) industries and private foundations should increase their support of basic research in chemistry.

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^{*}Research efforts in industrial establishments, Survey Report No. 5 (Survey & Planning of Scientific Research Unit, CSIR, New Delhi), 1965.

TN recent years, considerable progress has been made in classifying and understanding the ground state properties of nuclei. This has been possible mainly because of the discovery of the existence of shell structure, collective behaviour and superconducting aspects of nuclear matter. However, our understanding of nuclear reactions is still rather unsatisfactory. The present models for explaining these processes such as the compound nucleus and the direct interaction process lead to some conflicting situations. The study of nuclear reactions has been mostly confined to cases where only a single nucleon, photon or a light nucleus is absorbed or emitted. In this respect the process of fission of heavy nuclei is unique. With comparatively small amounts of energy required to initiate the process, it is found that the reaction proceeds in such a way that the nucleus divides into almost two equal parts, at the same time releasing a large quantity of energy, as the reaction having a high Q value. It is to be expected that since several nucleons are involved in the process, the study of nuclear fission can give considerable information on the collective behaviour of nucleons.

It is well known that the fission reaction forms the basis of the nuclear chain reaction, and it is strange that while this reaction has been so extensively used for the production of economic nuclear power, we are only just beginning to understand the details of the process. A complete understanding of the process involves the explanation of all observed facts, some of which have found an explanation consistent with ground state properties of nuclei.

A picture of the fission process was first given by Niels Bohr soon after its discovery in 1939, using the analogy between a nucleus and a charged liquid drop, the short-range nuclear forces being idealized as a surface tension. On this picture, it is to be expected that starting with an initial spherical or nearly spherical nucleus and ending as two separate fragments the original nucleus must have gone through a series of distortions. It is known that though the fission process is excergic for all heavy nuclei, fission takes place only if the process is initiated by supplying a small amount of energy in most cases. This implies that there exists an energy barrier for the process. The existence of such a barrier can easily be understood on the basis of Bohr's liquid drop model. In the beginning of the process, the increase in the surface energy of the nucleus due to a small deformation is greater than the corresponding decrease in the Coulomb energy. Hence, the potential energy of the system increases with increasing distortion initially. However, after a certain stage, the decreasing Coulomb

*Evening lecture delivered by Dr Raja Ramanna, Director, Physics Division, Atomic Energy Establishment, Trombay, Bombay, on the occasion of the presentation of the Shanti Swarup Bhatnagar Memorial Award for Physics for the year 1963, New Delhi, 29 July 1966.

energy overrides the increase in the surface energy and hence the potential energy of the system decreases, thus favouring further distortion leading to the ultimate division of the nucleus. A typical plot of the potential energy of the system versus distortion is given in Fig. 1. Three important stages in the process of fission can be recognized in Fig. 1. The first is the fissioning nucleus in its ground state. or the excited compound nucleus when external energy is supplied to the fissioning nucleus. The second is that stage in which the fissioning nucleus has the critical deformation necessary to take it over the energy barrier. This stage is usually known as the saddle point and the minimum energy necessary to bring the nucleus to the saddle point is the threshold energy for the process. On fairly simple considerations of the increase of surface energy and the decrease of Coulomb energy for given type of deformations of a nucleus, Bohr was able to derive simple expressions for the fission thresholds of many nuclei. It was also shown that no nuclei could exist without fissioning if it had a charge and mass such that $Z^2/A > 50$.

In order to initiate the process, one can supply the threshold energy by any method. If neutrons are used to initiate the fission process, it is found that even neutrons of very low energy are sufficient to cause fission in odd mass nuclei like U235, U233, Pu²³⁹, etc., whereas neutrons having an energy of about 1 MeV. are required for the fission of Th²³², U²³⁸, etc. The semi-empirical formula gives a simple explanation of this even-odd behaviour. The threshold energy needed to initiate fission is somewhere in the region of 5 MeV. for most of the heavy nuclei. The binding energy of a neutron in eveneven nuclei is about 5 MeV., but is only about 4 MeV. in the case of odd nuclei. So, one has to supply the extra 1 MeV. in cases where the neutron bombardment leads to a fissioning compound nucleus of odd mass.

If a threshold energy has to be supplied for fission to take place, it is clear that from quantum mechanical considerations fission can also take place by leaking through the potential barrier. All heavy



Fig. 1 — Potential energy curve of a fissioning nucleus at different stages of deformation

TABLE	1	 OF	log10	(HALF-LIFE)	FOR	DIFFEREN
			NUC	LEI		

Fissioning	\log_{10} (half-life in years)			
nucleus	even-even	odd mass		
Th232	18.15			
U232	13.90			
U284	16.30			
U235		17.26		
U236	16.30	1911 1913		
U238	15.90			
P11236	9.54			
Pu 238	10.69			
P11239	10 07	15.74		
P11240	11.08			
Pu ²⁴²	10.86			
P11244	10.40			
Cm240	6.28			
Cm ²⁴²	6.86			
Cm244	7.15			
Cm246	7.48			
B1-249	7 10	8.78		
Cf246	3.32	070		
Cf248	3.85	N.		
Cf249	5 05	9.18		
Cf250	4.18	, 10		
Cf252	1.82			
Cf254	-0.70			
E 253	-0.10	5.48		
E-254	-0.30	5 10		
F 111	-0.30	1.30		
Fm256	-3.52	1 50		
T III	5 52			

nuclei have a certain probability that fission takes place spontaneously without the initiation by any external agency. It has been found that eveneven nuclei have a higher spontaneous rate than odd mass nuclei (Table 1). The rate of fission very strongly depends on the height of the barrier and the effective mass of the system. In recent years, nuclear theory has had considerable success in the application of the pairing model, where superconducting effects have been used to explain the energy gap in the energy level spectrum of nuclei. This pairing correlation of the nucleons has been shown to decrease the height of the fission barrier in the case of even nuclei as compared to that in the case of odd nuclei. The model, therefore, gives an indication as to why spontaneous fission rate is more in the case of even nuclei.

At the saddle point the nuclear system is in a high state of deformation. It is of great importance to determine the properties of the nucleus in this condition as it could determine the subsequent behaviour of the process. From our knowledge of the collective behaviour of nuclear systems from other branches of nuclear physics, we know that a deformed system can possess well-defined quantum rotational states (Fig. 2). One can, therefore, expect that at the saddle point the nucleus can have similar states with specified quantum levels. It was in fact shown by A. Bohr that the angular distribution of the fission fragments with respect to a given direction is determined by the saddle point states. In low energy fission, the angular distributions are isotropic, but if the incident neutron or any other particle causing fission has an angular momentum, the experiment shows that



Fig. 2 — Energy level spectrum of a fissioning nucleus at its ground state and at its saddle point

there is a strong anisotropy. For example, in the case of fast neutron fission, more fragments are emitted in the direction of a neutron than at 90° to it. It is clear that if the incident particle energy is gradually changed, so as to excite the levels one by one, each excited level will give rise to a new angular distribution. It has been experimentally observed that when the incident energy is changed, the angular anisotropy also changes consistent with a definite level structure.

Between saddle point and scission the dynamics of the system is somewhat obscure, but it definitely conditions the final properties of the fragments such as their mass, charge, etc. It has been known for a long time that in low energy fission, the nucleus does not divide into two equal parts. It has a distribution as shown in Fig. 3. The simple liquid drop model picture predicts that it should divide into two equal parts. The asymmetry of splitting seems to arise from a stochastic rearrangement of nucleons conditioned by nuclear shell structure between saddle point and scission. This shell-



Fig. 3 — Experimental fragment mass distributions in neutron induced fission of uranium-235 and uranium-238

stochastic approach has been given by my collaborators and myself recently and it is shown that the mass distribution in low and high energy fission and other observations can be explained in a satisfactory way using parameters taken from the ground state properties of nuclei only.

The suggested description of the process is of a very general nature and independent of any physical model such as the liquid drop. At the saddle point we can consider the system as dividing into two equal parts. Between the saddle point and scission, the two sides exchange particles in a random way. We can either consider it as an exchange of nucleons or a random motion of the point of rupture. Whatever be the actual process, the mathematical formulation of the phenomenon is the same. The final mass distribution is determined by a set of probabilities, each depending on the existing number of nucleons on each side, the corresponding densities of states and a transfer function which depends on the binding energy due to shell formation. If these probabilities are appropriately calculated, the theory of Markov processes can be applied to determine the mass distribution. In fission induced by higher energy particles, it is necessary to assume that the shell binding energy weakens when the nuclear temperature increases. The theory is also able to say something on the time of fission. Full details of the model have been reported earlier^{1,2}.



Fig. 4 — Theoretically derived fragment mass distributions compared with experimental results



Fig. 5 — (a) Number of neutrons emitted as a function of the mass of the emitting fragment; and (b) phenomenological model for explaining the neutron emission curve. Points A, B and C represent the point of rupture for the symmetric, most probable and the very asymmetric fission modes

Our results have been compared with those reported in literature in Fig. 4. The theoretical curves are to be corrected for neutron emission. The time taken between the start of the process and scission point is estimated to be not more than 10-20 sec. This is a very small time for any experimental observations. All our observations concerning the process are, therefore, after scission has taken place. The only way we can infer the conditions of the system prior to scission is by observing the mass, kinetic energy, excitation energy and angular correlations of the fragment. The fragments which recoil in opposite directions with a kinetic energy of 150 MeV. also have considerable deformation and excitation at the time of scission. This energy is responsible for the emission of various prompt radiations from the fragments. It has been known for some time that the number of neutrons and Y-rays emitted from the two fragments depends very strongly on the mass of the fragments (Fig. 5a). This remarkable distribution shows that even at symmetry, the light fragment is much more excited compared to its corresponding heavy fragment. The situation is reversed at distributions away from symmetry. Phenomenologically, this could be described as due to the presence of a neck connecting the two spherical fragments. If fission is essentially asymmetrical having a light fragment and a heavy fragment, it is clear that the excitation energy of each side will depend on which side the neck attaches itself to. The subsequent release of the deformation energy into excitation will rise to the observed distribution (Fig. 5b). The stochastic description of the process gives a simple explanation to this behaviour, if we consider the accumulation of energy in the light fragment as due to the random exchange of protons between the two sides. If the charges of the fragments are in the ratio of their masses, the proton leaving the heavy fragment will have more energy than the one



Fig. 6 - Experimental arrangement

from the light fraction. This leads to the familiar zig-zag shape curves.

Considerable work has been carried out at the Apsara reactor at Trombay on the emission of prompt neutrons, Y-rays and a-particles emitted during fission. A detailed study of the nature of emission of these radiations is of great importance in fission theory. The energy spectrum of the neutrons emitted in fission can be studied from the time the neutrons take to move over a fixed known distance. This spectrum can be obtained for different angles of emission with respect to the fission fragments. The experimental arrangement used for making such measurements at Trombay is shown in Fig. 6. The observed spectra depend on the temperature and velocities of the emitting fragments. Besides, if all the neutrons are not emitted from the recoiling fragment, from a study of the angular correlation we can estimate how many neutrons come before and after scission. Our results which have now been confirmed by others show that about 10 per cent of the neutrons are emitted before scission and the phenomenon is analogous to evaporation. The other 90 per cent of the neutrons are emitted from fragments having a linear distribution of temperatures. Another important finding of the work carried out at Trombay is the existence of a high angular momentum or spin of the fragments. This indicates that at the time of scission the fragments are in a high state of distortion and after breaking up the two fragments not only fly in opposite directions but rotate with a high spin. These results were obtained by observing the angular distribution of prompt Y-rays in fission.

The emission of α -particles in fission has been a subject of controversy. They could be emitted before scission, at scission or after scission. If one can find out the stage at which they are emitted, several features of the process can be understood, but the experimental results have not been conclusive till recently. From a study of the angular distribution of the particles and fission fragments with respect to the fast neutron initiating fission, it is possible to determine whether the α -particles are emitted prior to scission or not. Preliminary results from a study of fragment angular distributions in ternary fission show that they are emitted prior to scission. This has lead to a new theory of α -particle emission, based on evaporation of the



Fig. 7 — Fragment angular anisotropy as a function of the mass asymmetry

prescission nucleus. The experimental results which point to this new approach are to be further repeated with better accuracy. These experiments have been carried out at Trombay using the 5.5 MeV. Van de Graaff machine and solid state detectors.

Another important contribution to fission studies resulting from our work using the Van de Graaff machine is the connection between the asymmetric formation of the fragment at scission, and the angular distribution of the fragments with respect to the neutron direction in fast neutron fission. The latter is assumed to be determined by the saddle point and any correlation between asymmetry of mass and anisotropy of angle will connect the properties of saddle point with scission. Our results show a small but definitely observable correlation (Fig. 7). The experiment is a difficult one and should be repeated because of its far-reaching consequences to the theory.

The study of fission has also given rise to investigations on two new aspects of nuclear structure. The first is the study of highly deformed nuclei available in the form of saddle point states during



Fig. 8 — Number of X-rays emitted as a function of the mass of the emitting fragment in spontaneous fission of californium-252

fission. The spectroscopy of such states will tell us more on the collective behaviour of deformed systems. The other, perhaps of even more direct importance to nuclear structure, is the study of the spectroscopy of highly neutron-rich nuclei available in the form of fragments. Such nuclei are available only in the fission process, each fission event corresponding to a separate pair of neutronrich nuclei. At present there is no way of obtaining such nuclei either with heavy ion accelerators or reactors. New developments in X-ray spectroscopy such as the Li-drifted silicon solid state detectors, high resolution solid state detectors for fragment detection, elaborate data acquisition systems and on-line computers for data analysis have given a new impetus to such investigations. It has been possible to determine the nuclear charge of fragments directly by a high resolution study of the X-rays emitted. These methods could be extended for studying the excited states of highly neutronrich nuclei having high spin which offer a most promising field. The number of X-rays emitted per fission in the spontaneous fission of californium-252 is shown as a function of the fragment mass in Fig. 8. Similar studies are in progress at Trombay on the thermal neutron induced fission of uranium-235.

On such an occasion, it is only my duty that I should express my deep feelings of gratitude to my late Director, Dr H. J. Bhabha. It has been said that such people come rarely in the history of a nation. I can only recall with happiness the great privilege given to me to have been able to work with him closely for nearly 16 years.

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Crystal Growth & Polytypism*

THE application of X-ray diffraction methods to the study of the internal atomic structure of solids has revealed that almost all solids are crystalline. They consist of a regular periodic arrangement of atoms, or a group of atoms, in three dimensions. This is true even of such solids as plastic, hair and wool. The exact arrangement of atoms inside a solid material is called its crystal structure, and most chemical compounds normally crystallize into definite crystal structures, each with a definite symmetry, unit cell, and number of formulae units per cell. Thus, sodium chloride, whether obtained from the sea or prepared in the laboratory or found as a mineral, has always shown the same arrangement of sodium and chlorine atoms at the same distance from each other. But there are some substances which crystallize into more than one structure and this property is called polymorphism. A classical example is that of calcium carbonate, which as the mineral Iceland spar was the subject of much study because of its striking property of double refraction. The formation of two images of an object when viewed at an angle to the trigonal axis of the rhombohedral cell could not be satisfactorily explained on the basis of Newton's corpuscular theory of light, whereas on the basis of Huygen's wave theory of light, the phenomenon could be well understood. Aragonite, another mineral with the same chemical formula, did not show this property because of the different spatial relationship of the carbonate groups in the orthorhombic unit cell. To the chemist the two modifications are one and the same substance, $CaCO_3$; but to the crystallographer they are two different crystals with different structures and different physical properties.

Polymorphism

This phenomenon of polymorphism is now fairly well understood, and the different structural modifications are known to be definite thermodynamic phases whose relative stability depends on the conditions of temperature and pressure. In fact, a majority of substances has been found to undergo structural transformations when subjected to extremes of temperature and pressure, and the phenomenon is known to be quite general. Thus, sodium chloride undergoes a polymorphic transition to a cesium chloride type structure when subjected to a pressure of about 18,000 atm., and the graphite form of carbon has been converted to diamond under a pressure of 55,000-100,000 atm. at a temperature of 1200-2400°C. However, the synthetic diamonds made so far are small and the process uneconomical.

Polytypism

There is a special kind of one-dimensional polymorphism, called polytypism, which is quite different from the ordinary polymorphism in that it appears to lack the thermodynamic or phase aspect. This is exhibited by certain close-packed and layer structures like silicon carbide, zinc sulphide and cadmium iodide. The structure of these substances is built up of identical layers of atoms stacked on top of each other at regular intervals. Each such

^{*}Based on the Dissertation by Dr Ajit Ram Verma, Director, National Physical Laboratory, New Delhi, on the occasion of the resentation of the Shanti Swarup Bhat-nagar Memorial Award in Physics for the year 1964, New Delhi, 29 July 1966.

substance displays a large number of structural modifications, called polytypes, which differ only in the manner of stacking these layers on top of each other. The layers themselves in any polytype are identical and so are the forces holding the atoms together. There is no effect of temperature or pressure on these modifications and they have nearly the same physical properties. There is an unlimited number of modifications for each substance and these do not transform into one another. Thermodynamically they have very nearly the same free energies and cannot be regarded as different phases of the compound. The most striking feature is the continued repetition and the stacking sequence of the layers, often with perfect crystalline regularity, after more than a hundred, or sometimes even a thousand, layers. Such enormous repeat distances, of the order of 250-2500 A., are rare in the inanimate world but common in the crystalline viruses and other biological specimens. Well-known examples are turnip yellow mosaic virus (f.c.c., $a \sim$ 700 A., diamond structure) and some of the fibrous proteins ($\sim 100-1400$ A.). What could be the nature of the forces and the mechanism that can cause such a long-range periodicity in the polytypes ? No atomic forces known to physicists till now have such a long-range influence, and it is this question that has held our attention for the last many years and which has yet to be answered satisfactorily.

It may appear to the layman that this is a purely academic question of limited significance. But it is these oddities of nature which must be investigated and explained if we are to know the true nature of interatomic forces in solids. It is in these that nature has left warnings for the scientist that he is yet far from his goal of a complete understanding. The progress of science has always hinged itself on the study of such exceptions.

Dislocation Mechanism

Several different theories have been put forward to explain the phenomenon of polytypism. Most prominent among these is the one suggested by Frank and is based on the dislocation mechanism of crystal growth. It is now well known that crystals grow from solution or vapour, at low supersaturations, by spiral growth around screw dislocations. It is believed that crystalfization begins with the formation of a thin platelet of microscopic dimensions, which gets self-stressed due to a nonuniform distribution of impurities or due to one of the several other causes. This stress is relieved by one portion of the platelet slipping past another, over a slip plane, thus creating a screw dislocation in the crystal platelet. This raises a terminated step on the surface of the crystal, the step being anchored at one point but free to rotate round this point as crystallization proceeds. The step height has molecular dimensions. The step is self-perpetuating during the growth and thus growth at low supersaturations continues. There are two consequences of this mechanism: (1) after growth is complete the crystal surface should be left with a spiral marking whose shape should be in accordance with the symmetries of the crystal face exhibiting it; and (2) the step height of these growth spirals should be simply related to the size of unit cells as determined by X-ray diffraction methods.

When these ideas were put forward around 1950, it was at first thought that these molecular growth spirals would not be observable. However, on the (0001) faces of silicon carbide crystals, by using phase contrast microscopy, I was able to observe a wide variety of growth spirals. For a precise determination of the spiral step heights which were of the order of 10 A., I employed Tolansky's technique of multiple-beam interferometry. The step heights were found to be equal to or simply related to the X-ray unit cell size. The screw dislocation theory of crystal growth was thus verified.

An extension of this study was done on some polytypes of silicon carbide and a correlation between their step heights and the X-ray unit cell size was discovered. This led Frank to put forward the screw dislocation theory of the formation of polytypes. Accordingly, the height and the structure of the initial step formed on the crystal surface determined the polytype that would be formed. Polytypism thus can be explained as resulting from crystal growth: the pitch of the screw becomes the length of the unit cell and the need for ordering forces over long distances does not arise. Thus, as an example, an initial step of 100 layers would give rise to polytype in which the structure repeats after 100 layers. The explanation is both simple and convincing. A detailed study of growth spirals observed on different polytypes was made. A direct correlation between the step heights of growth spirals observed and the size of X-ray unit cells for a large number of polytypes was observed and we felt in 1957 that the phenomenon of polytypism had been satisfactorily explained.

Anomalies in Silicon Carbide and Cadmium Iodide

However, several workers, in particular Prof. Jagodzinski, had expressed doubts regarding certain aspects of dislocation theory of polytypism. We, therefore, undertook a detailed experimental investigation of the phenomenon of polytypism in silicon carbide and cadmium iodide in the first instance. The investigation consisted of the following aspects: (1) to grow well-developed single crystals of polytypic substances; (2) to observe, by phase contrast microscopy, the surfaces of these crystals for growth spirals; (3) to measure accurately the spiral step heights by Tolansky's multiple-beam interferometric methods; (4) to record X-ray diffraction spectra from the same crystal which had been examined optically; and (5) to determine the unit cell size and the detailed atomic structure of different polytypes.

Having obtained all the above experimental data about a crystal we set ourselves to interpreting it in two ways. First, to correlate the step height of the growth spiral with the height of the X-ray unit cell. Secondly, to examine whether the actual crystal structure could result from theoretical dislocations in any of the basic phases of the compound.

Such an analysis, performed for a large number of silicon carbide and cadmium iodide crystals, has revealed several anomalies that cannot be accounted for by the screw dislocation theory of polytypism.

Other theories advanced so far also do not explain the observations of the phenomenon of polytypism. A collected account of these recent observations on polytypism and the present position is given in the book Polymorphism and polytypism in crystals written by myself and Dr P. Krishna, published by John Wiley & Sons Inc., New York.

In conclusion, it should be pointed out that none of the existing theories of polytypism gives a completely satisfactory explanation of observed facts and the formation of such a large number of long period ordered polytypes, some with unit cell heights much larger than the range of any known atomic forces, needs to be theoretically reconsidered.

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Recent Developments in Synthetic Dyes*

WISH to present to you mainly our recent work on synthetic dyes, although my research group has also been engaged on the synthesis of sulphur, nitrogen and oxygen containing ring systems, cancer chemotherapeuticals, heterocyclic steroids and branched chain fatty acids (including a new and simple synthesis of mycolypenic acid, the major acid of tubercular bacilli).

Among the synthetic dyes, the quinonoid dyes occupy pride of place on account of their excellent tinctorial and fastness properties and their applicability both as vat dyes and disperse dyes. The vat dyes also provide a fascinating field of study to the organic chemist.

Apart from developing the technology of known anthraquinoid vat dyes which are widely used by the textile industry, we have also been engaged in the synthesis of new quinonoid dyes. These dyes are of great chemical and technical interest as vat dyes for cellulose and as pigments. In dispersed form they are also useful in dyeing reconstituted and synthetic fibres, such as cellulose acetate, polyamide and polyester. These dyes were prepared starting from 2,3-dichloro-1,4-naphthoquinone (1) and chloranil (2) by condensation with naphthols, o-carboxyarylides, and compounds containing a reactive methylene group in the presence of pyridine. All the intermediates used in the preparation of these dyes are of low cost and are readily available. This work, described in 20 publications, has been reviewed earlier¹.

Some of the typical dyes derived from (1) and (2) are given in Charts 1 and 2.

Dyes of the type (3) dyed yellow, orange and brown shades on cotton as vat dyes. The fastness of these dyes to all agencies was good, except that they were fugitive to chlorine due to oxidative degradation of the fused furan ring system. The 2,3-phthaloylpyrrocolines (2,3-phtholoylindo-

lizines) (4) dyed attractive golden yellow and yelloworange shades on cellulose acetate, nylon and tervlene, whereas (5) dyed an attractive fast reddish orange shade on cotton as a vat dye. All of these dyes have definite possibilities of commercial exploitation. Dyes of the type (6) have been patented by Ciba Ltd, Basle (after the publication of our papers describing these dyes), and recently marketed. These pigments of great beauty and fastness are likely to prove an excellent addition to the field of organic pigments.

The dyes (violet, brown, olive and grey) derived from chloranil (Chart 2), although of chemical interest representing as they do new complex heterocyclic ring systems, were unfortunately only of doubtful commercial value since most of them were rather fugitive, especially to chlorine. Here again the bispyrrocolines (8A) and (9A) dyed attractive and fairly fast violet and grey shades on cotton as vat dyes.

The structures of these dyes and their mechanism of formation have been completely elucidated¹.

Noncoplanar Quinonoid Dyes

Condensation of (2) with anthracene gave (10) which by processes similar to the above led to noncoplanar quinonoid dyes of the type (11) and (12) (Chart 3).

^{*}Based on the Dissertation by Dr B. D. Tilak, National Chemical Laboratory, Poona, on the occasion of the presenta-tion of the Shanti Swarup Bhatnagar Memorial Award in Chemistry for the year 1963, New Delhi, 29 July 1966.

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Chart 1 - Typical dyes derived from 2,3-dichloro-1,4-naphthoquinone



These noncoplanar dyes had similar or more solubility than the corresponding planar dyes, and yet they had little or no affinity to cotton (as vat dyes), cellulose acetate, nylon or terylene. Since the van der Waals' attractive forces were nearly the same in the planar and noncoplanar dyes, the low substantivity of the noncoplanar dyes to these fibres must be attributed to their noncoplanar character. Our work has afforded conclusive evidence regarding the essentiality of coplanarity in quinonoid dyes for dye-fibre affinity for cotton and the above synthetic fibres².

Synthesis of Dyes by Hydride Loss

Our recent work on the synthesis of a new series of highly interesting cationic dyes involves hydride transfer. A common phenomenon in organic chemistry is the transfer of hydrogen with a pair of electrons (hydride ion) from one carbon atom to another. Since hydride ion has no independent existence as such, the two participating carbon atoms between which hydride transfer can occur must be separated in the transition state only by the migrating hydride ion. The transfer of hydride will, therefore, be hindered by severe steric crowding. The transfer also involves oxidation-reduction.

A New Series of Thiacyanine Dyes

Our interest in hydride transfer arose out of our study of cyclodehydration of β -arylmercaptoethyl methyl ketone by treatment with polyphosphoric acid. This reaction led to the synthesis of an extremely interesting new series of blue and greenish



 $R = CO_2 Et$, CONHR, CONHAr

Chart 3 - Synthesis of noncoplanar quinonoid dyes



Chart 4 - Formation of thiacyanine dyes involving hydride transfer

blue thiacyanine dyes which are characterized by their high extinction coefficients approaching those of triphenylmethane dyes³⁻⁵ (Chart 4).

of triphenylmethane dyes³⁻⁵ (Chart 4). The steric factors (Tilak, B. D. & Panse, G. T., unpublished work) involved in the hydride transfer will be clear from Chart 5. The chart also shows the synthesis of novel cyclic sulphonium salts involving rearrangement of carbonium ions reported recently by us⁶. This work arose out of our studies on the stereochemistry of hydride transfer—a subject of considerable interest on which very little work has been reported in the literature.

We have also recently prepared several other cationic dyes from thianaphthalenium salts (Tilak, B. D. & Panse, G. T., unpublished work). Some of these are shown in Chart 6. Some of the thianaphthalenium derivatives dye attractive lemon-yellow and orange shades on nylon and terylene.

Synthesis of Triphenylmethane Dyes by Hydride Loss

We then turned our attention to the mechanism of formation of triphenylmethane (TPM) dyes, such as Malachite Green and Crystal Violet, from the corresponding leuco bases. The latter are excellent hydride donors and are readily converted to TPM dyes by hydride transfer to acceptors such as trityl chloride or even to weak hydride acceptors such as acetic acid, its chloro derivatives and the corresponding ethyl esters, sulphuric acid and incipient carbonium ions such as protonated ethanol. Hydride transfer was affected by various factors such as concentration, temperature, acidity, time and to some extent by dissolved air. The reactions involved are shown in Chart 7.

With good hydride acceptors such as chloranil and trityl chloride (where the TPM dyes were formed in quantitative yield) the corresponding reduction



Chart 5 - Steric factors involved in the formation of cationic dyes by hydride transfer



Chart 6 - Cationic dyes derived from thianaphthalenium salts and their spectral characteristics

products (tetrachlorohydroquinone and triphenylmethane) were readily isolated and identified, but the fate of the hydride in other cases is not yet known. In the latter cases the reactions have been studied only in high dilution $(2\cdot5-6\times10^{-4} \text{ g. mole}/$ litre) by measuring the dye formed spectrometrically. The possibility of air oxidation (free radical oxidation) of leuco bases was considered, but since careful exclusion of air as well as addition of a radical quencher do not substantially affect the yield of the dyes, this explanation by itself cannot entirely account for our results. We are inclined to believe that the formation of dyes under the above conditions is due both to air oxidation as well as hydride transfer⁷.

Synthesis of Other Dyes by Hydride Loss

It is conceivable that several other dyes may also be formed by abstraction of hydride at some stage of their synthesis by means of either inorganic oxidizing agents or organic reagents which function as oxidizing agents by abstraction of hydride. A typical case in point is the Scholl cyclization of 1,5-dibenzoylnaphthalene to 2,3,7,8-dibenzopyrene-1,6-quinone (Indanthrene Golden Yellow GK) by means of oxygen-AlCl₃-NaCl or by the action of dinitrobenzene-AlCl₃-NaCl. In the latter case cyclization undoubtedly occurs by hydride abstraction by means of dinitrobenzene. Nenitzescu and Balaban⁸ have earlier shown that Scholl condensation does involve hydride transfer.



Chart 7 - Reactions involved in the synthesis of triphenylmethane dyes by hydride loss

It seems likely that the formation of several other dyes and intermediates such as benzanthrone (from 1-benzoylnaphthalene by the Scholl condensation), dibenzanthrone (Indanthrene Dark Blue BO from 4,4'-dibenzanthronyl by alkali fusion or 4,4'-dibenzyl-1,1'-dinaphthyl by the Scholl condensation), isodibenzanthrone (from 3,9-dibenzoylperylene), Meldola's Blue and Methylene Blue may also involve hydride transfer reactions. In the latter two cases the quinone-imine intermediates present will act as hydride acceptors. We hope to study these reactions and will seek experimental proof by studying the action of hydride abstractors on the course of these reactions⁹.

Dyestuff Research - Prospect

Although the dyestuff industry is one of the oldest of organic chemical industries, the mechanism of formation of several of the technically important dyes is not yet clearly understood. If the mechanistic approach is applied to the chemistry of dyes, it is likely to fetch rich dividends both for organic chemistry and dyestuff technology. Now that the dyestuff industry has been well established in India, the emphasis for future work should shift from the search for 'know-how' to a deeper insight into the ' why ' of their synthetic sequences.

As a result of the flourishing school of dyestuff chemists and technologists established due to the leadership of Dr Venkataraman and the far-sightedness of the Council of Scientific & Industrial Research, New Delhi, I feel confident that India will not lag far behind other countries in future developments in synthetic dyes.

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Some Newer Structural Types in Sesquiterpenoids*

ODERN physical methods of isolation and structure determination, coupled with a better understanding of biogenetic and organic chemical mechanistic basis that is available today, have revolutionized the study of the chemistry of natural products. One of the fields in which the impact has been very impressive is sesquiterpenoids field. About a decade and a half ago, the structures of barely a few members were known in complete detail and only ten types of different skeletons had been reported. However, today, not less than fifty basic types are known and more will undoubtedly be discovered in future. The number of compounds for which complete structural details are available run, at present, into well over hundred. It may be pointed out that with the exception of one or two types, this large variety of complex skeletons are, apparently, elaborated by nature from a single precursor, viz. farnesyl pyrophosphate.

During the past few years our group at the National Chemical Laboratory, Poona, has been engaged in a study of chemistry of indigenous plant materials. Some of the work was in continuation of the work I had initiated earlier, while working at the Indian Institute of Science, Bangalore. We have been rather fortunate in discovering, during the course of these studies, four new skeletal types (A-D) of sesquiterpenes and it is the purpose of this lecture to briefly discuss these results.



Himachalane

The essential oil from Himalayan deodar (*Cedrus deodara* Loud.; Sanskrit: Devadaru; Hindi: Deodar) is a complex blend of sesquiterpenoids in which hydrocarbons predominate. From the hydrocarbon part, the two major sesquiterpenes have been isolated¹ and named α - and β -himachalene after *Himachal*, the abode of this lofty tree. Preliminary chemical studies¹ revealed that these compounds represent a new type in sesquiterpene carbon frame-

work. As a result of systematic degradation work and application of modern physical methods of structure determination, the structures of these compounds have been established^{2,3} as (I) and (II). Synthesis of the perhydro system (III) has also been achieved (Pande, R. C. & Sukh Dev, unpublished work).



As a part of evidence leading to their structure determination, a brief reference to the ozonolysis of β -himachalene should suffice. The hydrocarbon was ozonized and the ozonide oxidatively decomposed. The products were separated into the acidic and neutral parts and the latter subjected to base-catalysed cyclization. The compounds (IV to VIII) could ultimately be isolated and duly identified. The formation of these products, the genesis of which, from β -himachalene, is shown in Chart 1, constitutes a very cogent proof for the structure of β -himachalene.



The absolute stereochemistry of these terpenoids was, ultimately, correlated with that of longifolene of known^{4,5} absolute stereochemistry. These reactions are summarized in Chart 2.

It must also be mentioned that selenium dehydrogenation of himachalenes gives, besides some amount of the expected benzene derivative (IX), substantial quantities of cadalene (X) and 2-methyl-6-(p-tolyl)heptane (XI). Thus, in this context, it should be emphasized that the results of dehydrogenation should be interpreted with caution and it is quite conceivable that a himachalane-based sesquiterpene could have been earlier wrongly recognized as a cadalenic type.

After having established the structures of himachalenes, attention was directed to detecting and isolating their congeners, if any, in the essential oil. In this work gas-liquid chromatography (GLC),

^{*}Based on the Dissertation by Dr Sukh Dev, National Chemical Laboratory, Poona, on the occasion of the presentation of the Shanti Swarup Bhatnagar Memorial Award in Chemistry for the year 1964, New Delhi, 29 July 1966.


Chart 1 - Ozonolysis of β-himachalenc



thin layer chromatography (TLC) over silica gel silver nitrate⁶ — a most valuable technique in the field of terpenoids — and proton magnetic resonance (PMR) spectroscopy played a decisive role; since the PMR signals for the various methyls in himachalenes were known as a result of the earlier work, these served as 'sign posts' in detecting the congeners. As a result of this work four more members have been added to the new family and their structures settled (Bisarya, S. C. & Sukh Dev, unpublished work).





ar-Himachalene

XII

XIV Himachalol



XIII

Dehydro-ar-himachalene

Oxido-himachalene

Allohimachalol

Allohimachalol, a crystalline sesquiterpene alcohol (m.p., 67-68°), is also a constituent of *Cedrus deodara* and, in fact, can be separated from himachalol only with difficulty. During its structure determination, biogenetic considerations played a dominant role.

From chemical and spectroscopic evidence, it became clear that allohimachalol, $C_{15}H_{26}O$, is a mono-olefinic bicyclic secondary alcohol having three quaternary methyls and one vinylic methyl. These data and the other features of its PMR spectrum required that allohimachalol must belong to a new skeletal type.

In the search for a working structure for this compound, consideration of currently accepted biogenetic concepts for isoprenoids was invoked. At this point the biogenesis of the himachalenes must be considered first. As shown in Chart 3, the species (4), first suggested by Hendrickson' as the precursor for longibornyl cation⁸, can stabilize to furnish himachalenes and himachalol and since the longibornyl cation pathway to longifolene has been established by tracer studies⁹, the route suggested for himachalenes appears very plausible. It appeared that the new alcohol also could have possibly originated from species (4) as it could, by



Chart 2 - Correlation of himachalenes with longifolene

495



Chart 3 -- Possible biogenesis of himachalenes



a 1,2-shift, yield a skeleton which could fit the data briefly discussed above for this alcohol. This hypothesis could be proved in a rather simple and straightmanner. Allohimachalol tosvlate forward on solvolysis in aq. dioxane furnished approximately 3 per cent α -himachalene, 15 per cent β -himachalene, 24 per cent himachalol and 34 per cent allohimachalol. This reaction limits the possible structures for allohimachalol to (XVI), (XVII) and (XVIII). Since the ketone derived from dihydroallohimachalol could not be brominated, allohimachalol must be represented by (XVIII). Furthermore, the solvolysis experiment permits the unequivocal assignment of the configuration of the hydroxyl group in (XVIII), which must be anti-parallel to the migrating bond. Its absolute stereochemistry, as shown in (XIX), follows from that of himachalenes.

The ketone (XX) corresponding to (XIX) has also been isolated from *Cedrus deodara* and has been named allohimachalone.

Copane

During our study of the constituents of Cyperus rotundus (Sanskrit: Mustaka; Hindi: Motha), we isolated a new sesquiterpene ketone mustakone¹⁰ ($C_{15}H_{22}O$). While working on its structure it was found that the ketone has the partial structure (XXI) and this chromophore must be a part of a strained system as its $\lambda_{max}^{\rm EtOH}$ 255 m μ (ϵ 5700) occurs at a considerably higher wavelength than the normally expected value. Furthermore, it was established that the ketone is tricyclic and that its carbon skeleton is the same as that of a sesquiterpene hydrocarbon, copaene, first isolated in 1914 from the African Copaiba balsam oil¹¹.

The structure of copaene $accepted^{12}$ at that time was (XXII). As can be seen, the part structure deduced above cannot be fitted into this framework and hence the structure of copaene itself became a suspect and a reinvestigation was undertaken.

It was soon shown by chemical means that copaene does not contain a cyclopropane ring. Any new structural proposal for (-)-copaene must, besides



Chart 4 - Possible genesis of copaene



Chart 5 - Degradation of copaene



meeting the spectral requirements, also explain its key reaction, viz. conversion by hydrogen chloride into (-)-cadinene dihydrochloride (XXIII). Formula (XXIV)^{10,13} which may be derived (as indicated in Chart 4) not only explains all the known reactions of copaene but also uniquely meets the requirements of mustakone. This structure for copaene was next confirmed by the transformation shown in Chart 5, which clearly proves the presence of a four-membered ring in copaene.

Mustakone can now be represented^{10,14} as given in (XXV).

Recently, we have isolated another member of this interesting system and have shown it to possess the structure (XXVI) (Kapadia, V. H., Naik, V. G. & Sukh Dev, unpublished work).

Longicyclene

Lastly, I shall discuss the structure of longicyclene, a minor constituent of the Indian turpentine oil (ex-Pinus longifolia). This is the only tetracarbocyclic sesquiterpene known todate.

The hydrocarbon was readily shown to be devoid of any olefinic linkage and the presence of four quaternary methyls was clear from its PMR spectrum. On biogenetic consideration it was suspected that the compound may as well be the tricyclene analogue (XXVIII) of longifolene (XXVII). That this was indeed so was proved¹⁵ by its treatment with cupric acetate in acetic acid, when besides some longicyclene and isolongifolene¹⁶ (+)-longifolene (XXVII) was formed. The isolation of longicyclene from a natural source is of special interest, as it represents an alternate pathway for the stabilization of the longibornyl cation, the progenitor of longifolene.



It has now been shown (Nayak, U. R. & Sukh Dev, unpublished work) that the dehydrohalogenation of longibornyl bromide produces considerable quantities of longicyclene.

The only other known members of this class is Ψ -longifolic acid¹⁷, a product of chromic acid oxidation of longifolene, recently shown (Mehta, G., Nayak, U. R. & Sukh Dev, unpublished work) by us to have the structure (XXIX).

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THE history of the discovery of vitamins has been most fascinating. The so-called deficiency diseases like night-blindness, beriberi, etc., were known for ages and the cure for some of them was also known empirically. But, only after the turn of the century did the concept of 'accessory food factors' grow with the observations of Hopkins that young rats, which grew poorly on a purified ration, could resume normal growth when supplemented with just 3 ml. of whole milk per day. These were later on known as vitamins. Eventually, a whole series of them was isolated and chemically characterized. At the same time it was shown that the vitamins belonging to the water-soluble B-group function as co-enzymes. No such co-enzymic role of the fat-soluble vitamins has yet been clearly established.

Vitamin A is one such fat-soluble vitamin. It is unique among all the vitamins in that no other vitamin is stored in such large amounts by the animal. Also, the deficiency of no other vitamin causes such widespread damage to most tissues as that of vitamin A. This vitamin occurs in nature both in the preformed state and also in the form of its precursor, the pro-vitamin A carotenoids. The ultimate sources of the preformed vitamin A are its precursors, the carotenes, that are converted to the vitamin in the animal intestine.

Site of Conversion of Carotene to Vitamin A

Long before I started my career as a research scientist, it was stated in text-books and taught in class-rooms that the carotenes are converted to vitamin A in the liver. I was able to demonstrate during my work for the Ph.D. degree that, contrary to the then prevailing view that the conversion of carotene to vitamin A takes place in the liver, the actual site of conversion is the small intestine.

Absorption and Storage of Vitamin A

Vitamin A has a hydroxy group at the end of the polyene chain and probably this particular group plays a very important role in the metabolism of vitamin A. This group can be esterified, and in fact vitamin A exists in nature almost entirely in the esterified state. Nature has devised this ingenious mechanism for storing the vitamin, because the ester is far more stable than the free vitamin A alcohol. We were able to establish that both pancreas and small intestine of animals possess enzymes that can readily esterify vitamin A alcohol and hydrolyse vitamin A esters. These two enzymic processes play a vital role in the absorption, storage and metabolism of vitamin A. We have demonstrated that the dietary vitamin A esters are rapidly hydrolysed in the small intestine by the pancreatic and/or mucosal vitamin A ester hydrolase, after

which only the vitamin A alcohol gains entry into the mucosal cell. Once inside the cell, it is rapidly re-esterified and is then transported through the lymphatic system almost entirely as its palmitic acid ester. The ester is ultimately stored in the Kupffer cells of the liver, while the parenchymal cells contain small amounts of vitamin A alcohol. The vitamin A ester stored in the liver is slowly hydrolysed by the vitamin A ester hydrolase and the vitamin A alcohol is released into the blood stream, in the form of a protein complex, to meet the metabolic requirements of the tissues.

The vitamin A alcohol can be successively oxidized to the corresponding aldehyde (retinene) and the acid. It has been known for a long time that one of the classical symptoms of vitamin A deficiency is defective vision. But only recently has the precise role of vitamin A in this process been clearly understood and it has now been established that the aldehyde form of the vitamin functions in the visual system. However, the amount of vitamin A present in the retina of the eye is only a small fraction of the total amount of the vitamin of the whole animal body, and until recently the biological function of this major portion of the vitamin A of the animal body was not known.

Vitamin A Acid

Just a few years ago the whole field of vitamin A metabolism sprang into new life from the work on vitamin A acid. It was shown that rats can grow normally when supplemented with vitamin A acid instead of vitamin A alcohol, but such rats became completely blind. This observation made it obvious that the animals cannot convert the acid back to the aldehyde, because only the aldehyde form of the vitamin functions in the visual system. It thus became clear that vitamin A acid, or some compound derived from it, meets the requirements for growth. However, there was no quantitative evidence on the relative growthpromoting ability of vitamin A acid and vitamin A acetate in vitamin A deficient rats. We undertook to investigate this aspect; as expected, when compared to the acetate, vitamin A acid stimulated markedly more pronounced growth in these rats.

However, animals never receive vitamin A acid in their diet, the source of their vitamin being vitamin A alcohol or its esters or the carotenes. Therefore, it appeared logical that the animals should have the necessary machinery for producing the acid. Indeed, we showed that rat liver contains two enzyme fractions that can separately oxidize vitamin A alcohol to the aldehyde and the aldehyde to the acid. I have already mentioned above that rat liver contains vitamin A ester and vitamin A alcohol and also the enzyme to hydrolyse the liver ester. The only intermediate that was missing here was vitamin A aldehyde. The aldehyde was previously found only in the retina. But we conclusively demonstrated that rat liver also contains small but definite amounts of vitamin A

^{*}Based on the Dissertation by Dr J. Ganguly, Professor of Biochemistry, Department of Biochemistry, Indian Institute of Science, Bangalore, on the occasion of the presentation of the Shanti Swarup Bhatnagar Memorial Award in Biological Sciences for the year 1963, New Delhi, 29 July 1966.

aldehyde. Thus, we were able to prove that rat liver contains all the enzymes and intermediates necessary for constantly generating the vitamin A acid with the stored vitamin A ester as the starting material.

Soon after this, the entire work on vitamin A acid received a severe jolt. All work on vitamin A acid was carried out with the chemically synthesized compound, and no vitamin A acid was ever isolated from normal animal body, or from animals that had received the acid. It was, therefore, widely believed that the acid is neither absorbed nor stored by rats. Therefore, serious doubts arose as to whether vitamin A acid can at all be called a natural metabolite of the vitamin. These points had to be settled and we succeeded in showing that vitamin A acid is indeed very efficiently absorbed, but at the same time is rapidly excreted through the bile. At about the same time we also showed that when its immediate precursor, vitamin A aldehyde, is injected into a rat, large amounts of the acid are rapidly formed in the liver. But here also it is rapidly excreted through the bile.

How is it then that no vitamin A acid has ever been detected in animal liver? It may be worth while to ponder over the machinery nature has evolved for preserving such a vital commodity as vitamin A ester, while at the same time allowing only limited amounts of it to be used up. At high concentrations, vitamin A ester is highly toxic and it kills the animal. Vitamin A acid is toxic at much lower concentrations. Yet the animal always carries inside it such a potentially toxic material. Several regulatory blocks have been introduced in the entire sequence of reactions to control the over-production of the acid. Thus the liver can hydrolyse the stored ester, but at a very poor rate, and, thereby, only very small amounts of vitamin A alcohol are made available. The next controlling step is the oxidation of the alcohol to the aldehyde. In this reaction the equilibrium is far towards the alcohol, and, therefore, only very small amounts of the available alcohol can be oxidized at any given time. This explains why such small amounts of the aldehyde are to be found in rat liver, which automatically allows very small amounts of the acid to be formed. As discussed above, if large amounts of the aldehyde are made available to the liver, considerable amounts of the acid can be detected there. Therefore, the formation of the aldehyde controls the formation of the acid. If, in spite of so many controlling steps, excess amounts of vitamin A acid are formed, the acid is immediately excreted through the bile as a glucuronide.

Metabolic Function of Vitamin A

The only definite information we have on the metabolic function of vitamin A is that it is essential for the visual system. This vitamin seems to be required in most other tissues also, but the precise mechanism of its action is still obscure. We have been able to collect some evidence regarding its role in at least one more area, viz. steroidogenosis. Earlier classical work had demonstrated that vitamin A is required for the normal reproduction

of both male and female rats. But this type of work had an inherent drawback in that during vitamin A deficiency many tissues undergo severe damage so that failure of reproduction under such circumstances was obscured by the pathological derangements of the tissues. This difficulty was surmounted by us. We showed that although both male and female rats can grow normally and appear perfectly healthy when they are supplemented with vitamin A acid, instead of vitamin A acetate, they fail to reproduce. Further investigation in our laboratory showed that vitamin A is required for the enzymic conversion of pregnenolone to progesterone. This work has immense possibilities, because not only has it shown some sort of co-enzymic function of vitamin A, but it may also lead to a better understanding of some of the modes of action of this vitamin.

Vitamin A and Protein Malnutrition

Thus far I have narrated some of the highlights of our fundamental work on vitamin A. It would be of interest to know that this fundamental knowledge has been of some use in the alleviation of human suffering. The major deficiency disease of the world today is protein malnutrition. Infants and children of the developing countries are usually victims of this disease, which has been called 'Kwashiorkor'. It has been a common experience of the clinicians that usually the kwashiorkor children suffer from vitamin A deficiency also. We became interested in this problem and our investigations with rats have shown that the intestinal absorption of vitamin A, its mobilization from liver in blood and the oxidation of vitamin A aldehyde to the acid are seriously affected by inadequate protein intake, thereby leading to vitamin A deficiency. Usually, there is little preformed vitamin A in the diet of the segments of the population that suffer from protein deficiency, their only source of the vitamin being the pro-vitamin A carotenoids. We have shown that the intestinal conversion of β -carotene to vitamin A is severely affected in protein-malnourished rats. This is most serious because, as it is, the dietary source of β -carotene of the kwashiorkor children is very poor, and on top of it, whatever is present in their diet is not fully utilized.

Mechanism of Biosynthesis of Fatty Acids

All this time I have been talking about our work on vitamin A, which is indeed our major activity. A few years ago, I happened to work on the mechanism of biosynthesis of fatty acids. After the work on the oxidation of fatty acids was completed, it became generally accepted that the synthesis of fatty acids would be a simple reversal of oxidation. But, contrary to this generally accepted view, we were able to establish a completely unexpected mechanism in the process. We showed that the acetate is first carboxylated to malonate which then condenses with another molecule of acetate to give rise to butyrate, through a sequence of reactions. The butyrate then condenses with yet another malonate and thus the chain elongation takes place. This work of ours was at that time

one of the most exciting events in biochemistry and was hailed all over the world. It is now called the Wakil-Ganguly scheme of fatty acid synthesis and is being taught in class-rooms.

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AN has been long concerned with the improvement of useful plants. The early, workers practised plant breeding mainly as an art. Its development as a science followed the discovery of Mendel's laws of heredity in the beginning of the present century. Since then, the science of plant breeding has made a very significant contribution in increasing agricultural production. The present-day crop varieties are vastly different from those of the past. The genetic recombination has demonstrated the unending possibility of combining valuable characters from different sources. Theoretically, there are no limits to the extent of improvement that can be brought about in yield and other desirable characteristics employing various plant breeding techniques. There is every reason to believe that advances in crop improvement made up to the present day have not taken us even near to the maximum productivity that is possible.

Plant breeding involves relatively long range and patient research. Generally, it takes 10-12 vears to develop a new variety. The discouraging feature of this time lag in the completion of a plant breeding project can be partially offset if the work is expedited by advancing two or three generations of a crop in one year. In majority of the research projects we have been content with a gain of 10-15 per cent in the yield level of a new strain developed over a period of many years. However, there are some instances of spectacular increases in the yielding capacity of new crop strains amongst which the development of hybrid maize and dwarf wheat in USA and Mexico should figure very prominently. No doubt such scientific achievements have resulted in major break-through in agricultural production.

Importance of Bajra as a Food Crop

Pearl millet (*Pennisetum typhoides*), which is locally known as *bajra*, is an important foodgrain crop of short duration in India. It is cultivated annually over an area of about ten million hectares and ranks fourth in acreage after rice, sorghum and wheat. Being the most drought tolerant cereal, *bajra* is the staple crop in arid coarse-textured soils. More than 90 per cent of the area under this crop is rain-fed and its present average grain yield is only about 326 kg. per hectare. *Bajra* is also grown in other Asian and African countries. In USA it is almost exclusively grown for forage.

In spite of the importance of *bajra* as a foodgrain crop, research for its improvement did not receive adequate attention until recently. For a long time it was considered a difficult crop to improve. On account of the pronounced protogeny, it is a highly cross-pollinated crop, the percentage of crosspollination being about 80. Improved varieties were evolved through mass selection. These tended to be lost if constant attention was not paid to their maintenance. More than two decades ago, work was taken up in India to develop high yielding hybrids. The usual method for the production of hybrid seed was to grow the parental lines in mixture and let them cross among themselves. The resultant produce was expected to contain a maximum of 40 per cent hybrid seed if the two parents flowered about the same time. The hybrids developed in this manner were released for cultivation in Madras and Maharashtra. However, the superiority of these hybrids over the open pollinated varieties ranged from 10 to 25 per cent only. They had a narrow range of adaptability and failed to perform better than the open pollinated varieties in other states.

Production of Hybrid Seed

The lack of a practical method to produce 100 per cent hybrid seed was the main limitation in exploiting the phenomenon of hybrid vigour for increasing the yield of bajra crop. The cytoplasmic male sterility offered the only mechanism for largescale production of hybrid seed. The occurrer.ce of male sterility was reported in India about a decade ago, but no work was undertaken to utilize it for the production of hybrid seed. In USA, a cytoplasmic male sterile line as well as fertility restorer lines had been developed by 1958, but the male sterility does not appear to have been used for the production of hybrid seed, most probably because the crop is grown there primarily for forage. In a project for the development of hybrid bajra, extensive inbreeding in selected varieties was undertaken in 1959 in the Punjab. In 1961, a cytoplasmic male sterile line was discovered at Ludhiana. In 1962, the seed of the US male sterile line also became available. In the same year another male sterile line was identified at Ludhiana.

Breeding and Improvement of Bajra

The discovery of cytoplasmic male sterility at Ludhiana and the utilization of the US male sterile line offered new opportunities in the breeding and improvement of bajra. Besides male sterile lines, a large number of valuable stocks of genetic and breeding interest were isolated at Ludhiana. The most important of these were the ones with very long bristles and bold and pearly amber grains and the dwarfs. The bristling was found to confer bird resistance. The bold and pearly amber grains appeared to offer scope for improving grain quality. Amongst the dwarfs, the most promising one had very long ears and could be utilized for the development of hybrids responsive to heavy manuring. The potential value of the male sterile lines for the development of hybrid bajra and the practical utility of other genetic stocks was clearly recognized and future breeding procedures were outlined in a paper which appeared in 1963. It was concluded

^{*}Based on the Dissertation by Dr D. S. Athwal, Professor of Plant Breeding, Punjab Agricultural University, Ludhiana, on the occasion of the presentation of the Shanti Swarup Bhatnagar Memorial Award in Biological Sciences for the year 1964, New Delhi, 29 July 1966.

that the availability of these materials present many new possibilities and predicted that planned breeding programmes would soon prove that baira which had been considered in the past as less amenable to improvement, in fact, offers greater scope than many other crops.

The research work designed to evolve hybrid baira was expedited by advancing two to three generations of the material in a single year. The results obtained in the Punjab had proved that it was possible to raise an additional crop from March to June for experimental purpose. From 1963 onward, a third crop in a year was taken in South India at Coimbatore during winter months from November to February. Development of bajra hybrid that would have normally taken a period of about 10 years was thus completed within four years. By 1963, several hybrids based on male sterility became available and these were tested in yield trials conducted at different locations in the Punjab to compare their performance against the previous standard varieties. The most promising hybrid showed spectacular increase in yield over the standard variety. Some of the best hybrids were included in All-India Coordinated Trials in 1964. Two of the hybrids, namely Tf 23A × BIL-3B and L 101A × BIL-3B, gave very good performance. The first hybrid is the result of a cross between a highly improved pollinator strain developed at Ludhiana and the male sterile line obtained from USA. The second hybrid is a cross between the same pollinator and a male sterile line developed at Ludhiana. On the average of 16 trials in all the important bajra growing states, hybrids Tf 23A \times BIL-3B and L 101A \times BIL-3B yielded respectively 100 and 89 per cent higher than the standard varieties.

Suitability of Hybrid Bajra for Cultivation in India

In view of the outstanding performance of hybrid Tf $23A \times BIL-3B$, the Central Variety Release Committee of the Indian Council of Agricultural Research released it for cultivation in March 1965 and named it as Hybrid Bajra No. 1. This hybrid is capable of yielding nearly twice as much as the previous improved varieties and is suitable for cultivation in all the bajra growing states from Punjab in the north to Madras in the south. Yields up to 2500 kg. per hectare have been easily obtained from this hybrid under rain-fed conditions. It has wide range of adaptability and is also suitable for cultivation under high fertility and irrigated conditions. In demonstration plots, laid out with Hybrid Bajra No. 1, yield of over 5000 kg. per hectare has been reported from the cultivators' fields. The hybrid possesses a high degree of resistance to lodging, drought and green ear disease. The grain is fairly high in protein content and is comparable with local bajra in quality and acceptability. The hybrid matures in about 85 days from sowing and is characterized by profuse tillering and uniformity in earing.

Inheritance of Male Sterility in Ludhiana and US Lines

Studies were initiated in collaboration with Dr G. W. Burton who developed cytoplasmic male sterile line of bajra in USA to determine the inheritance of male sterility in Ludhiana and US lines under two different environmental conditions. The observations made both at Ludhiana and at Tifton in USA have confirmed that the cytogene mechanism controlling male sterility in the Ludhiana lines is entirely different from that of the US line. It was interesting to find that many inbreds incapable of restoring fertility of the US line acted as restorers on the Ludhiana male steriles. The frequency of the gene capable of restoring fertility in the US male sterile was rather low and a large percentage of the inbreds developed as pollinators had to be rejected, because they were non-restorers. The finding that the Ludhiana male steriles are different has added new dimensions to bajra breeding programmes. It will be possible to use a wider range of material as parents of future hybrids. The male sterility of three different sources (one from USA and two from Ludhiana) has now been incorporated into several improved inbreds. A series of male steriles representing a wide range of genetic diversity and maturity periods have been developed. Some of these lines appear to be considerably better than the previous ones and are expected to make useful contribution in future research on the improvement of bajra.

Bajra - an Ideal Plant for Genetic Studies

Bajra, which at one time appeared difficult to improve, offers many advantages. Its low seed rate on account of small seed size is a redeeming feature in hybrid seed production. The work can be expedited by taking three crops in a year. The seedlings of bajra can be successfully transplanted and if the seed is first sown in the nursery, one hectare can be planted with seedlings raised from about half a kg. of seed. This facilitates the increase of seed of valuable material at a tremendous rate of multiplication. It is a very suitable plant for genetic studies. It has many contrasting characters and a small number of chromosomes. Studies are now in progress to collect comprehensive information on the inheritance of various characters as well as their linkage relationship. With the availability of such basic information, the current breeding procedures will lead to even more significant achievements in the improvement of this crop.

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The Problem of Peptic Ulceration : An Experimental Study of 'Gastric Mucous Barrier'*

THE clinical features of peptic ulcer have been known from ancient times. Hippocrates described the characteristic features of the disease. In their writings Celsus in the first and Galen in the second century vaguely referred to the ulcers of the stomach. However, the pathology of the disease was studied in fair detail in the sixteenth century when autopsy was revived, and in 1586 Marcellus Donatus reported the first case of peptic ulcer in European medical literature. Cases of gastric ulcer have been described by Littre in 1870 and Trier of Copenhagen published his monograph on duodenal ulcer in 1863. Besides the gastric and the duodenal ulcer, ulcers may occur in the oesophagus and in the jejunum after gastrojejunostomy. This type is, however, rare. Histo-pathologically, two distinct types, the acute and the chronic ulcer, are recognized. The so-called sub-acute ulcer remains still a subject of controversy. Because of the direct physical relation of these ulcers to acid-pepsin of the stomach a conceptual unity has been maintained and peptic ulcer is used as a comprehensive term.

Peptic ulcer has been reported from all over the world. In India, there is a very high incidence of this ulcer in south in the age group of 20-40 years and this constitutes a serious problem of national importance. In the south, it is a disease of the poor agricultural and labouring classes and is relatively uncommon in the upper classes. The incidence of duodenal ulcer exceeds greatly the gastric ulcer and pyloric stenosis occurs with considerable frequency. In Europe, on the other hand, there is a high incidence of duodenal ulcer among doctors and executives, but in the agricultural and labouring classes the incidence is remarkably low. This social and occupational difference in the incidence of peptic ulcer in India as compared to the West is indeed interesting. The constitutional factors, sex and age factor, blood group relationship, heredity and personality factors have all been clinically investigated all over the world. Besides these, a large number of factors have also been investigated in experimental animals and the present dissertation is confined to this aspect.

To establish a relationship of food to peptic ulceration attempts have been made to induce ulcer by the administration of food deficient in vitamins and proteins, but the results are inconclusive. The neurogenic theory has also been put to extensive experimentation and sections at all levels of spinal cord, splanchnic nerves and vagi, introduction of foreign bodies in the brain and injections of all kinds of drugs have been made, but all of these have given contradictory results. The theory of circulatory

disturbances has led to series of investigations. The introduction of emboli-like sterile oil, lead chromate. bees-wax, fibrin in the blood vessels, ligation of gastric vessels, and interruption of circulation by local spasm, produced by drugs have so far produced only erosions. As regards the association of endocrine glands to peptic ulcer Cushing in 1932 described peptic ulceration in cases of cerebral haemorrhage and tumors, and Winkelstein in 1945 association of the pituitary to duodenal ulcer. Since then the study on the role of endocrine glands and stress factors have formed an important line of work. Experimental studies on the emotional states and psychosomatic factors have been done on human subjects, but there is no definite evidence that exaggeration of these functions leads to ulcer formation. Last and by far the most important are the studies on the relationship of the direct role

of gastric secretions to peptic ulceration. We have postulated during the course of our studies in experimental peptic ulceration with particular reference to gastric secretion that, in the development of ulcer, two opposite forces operated on the gastric mucosa and termed them the aggressive and the defensive forces respectively. We suggested that the aggressive factor was the acid-peptic activity and in defence there was only one main factor - the gastric mucin. If the aggressive factor was strong and the defensive weak, ulcer developed. An enormous amount of work has been devoted in the past to the study of acidpeptic secretion, but very little is known about the physiological mechanisms underlying the production of gastric mucus and its role in the prevention and healing of peptic ulceration. Our main experiments were aimed at the investigation of this important aspect of the peptic ulcer problem.

Significance of Mucous Barrier in Acute Peptic Ulceration

During the production of acute gastric ulceration by massive doses of histamine (100 mg./kg.) induced in guinea-pigs protected with antihistaminics, we observed that the intensity of ulceration was much lower in the stomach which had sufficient gastric mucin contents. This led us to investigate the importance of mucus. In our experiments we studied whether exaggerated mucus secretion would prevent ulceration. We provoked mucous secretion in guinea-pigs with capsicum — an important garnishing agent and the most common among the spices used in India. We fed the experimental animals with capsicum (1.0 g./kg.), in the form of a suspension, which was followed by histamine induced ulceration. We found that capsicum provoked mucous secretory activity and the more the production of mucus, the less was the degree of ulceration. Mucus also protected the mucosa and the sub-mucosa from inflammatory reactions. Further, we observed that the higher the mucin

^{*}Based on the Dissertation by Dr S. H. Zaidi, Director, Industrial Toxicology Research Centre, Lucknow, on the occasion of the presentation of the Shanti Swarup Bhatnagar Memorial Award in Medicine for the year 1963, New Delhi, 29 July 1966.

content in the gastric juice, the lower was the free acidity. We recognized this as an evidence that mucin neutralized the action of acid gastric juice; also adhered to the surface of the mucosa and formed what we have called it as a 'barrier' against peptic ulceration.

The significance of mucous barrier was also studied in acute phenylbutazone induced gastric ulceration in guinea-pigs. Ulceration was produced by intraperitoneal injection of single dose of phenylbutazone (200 mg./kg.). Superficial haemorrhage, haemorrhagic erosions, degenerative patches and deep acute ulcers showing delayed healing were noted. This was associated with a significant decrease in mucin from 24 to 48 hr. These changes in the gastric mucosa were suggested to be due to direct effect of the drug on the mucous cells causing a damage of the 'mucous barrier'.

Mucous Barrier and the Healing Process

The significance of mucous barrier was investigated in the healing process of experimental peptic ulceration induced in guinea-pigs by massive doses of histamine. During the process of healing, studies of the gastric juice showed significant increase in mucin values from 96 to 384 hr related to the degree of healing. This showed the role of mucin in the healing of experimental ulcers.

Mucous Barrier in Chronic Peptic Ulceration

Experimental production of chronic ulceration has always been a matter of great interest. The chronic ulcer which could be experimentally produced in the past was the counterpart of human post-gastrojejunal ulcer. Another type of chronic ulcer which resembles histopathologically that of man was with the administration of the drug cinchophen (2-phenylquinoline-4-carboxylic acid) to dogs. The mechanism of this ulcer has remained uncertain. Local damaging action of cinchophen on the mucosa, initial hypersecretion of acid, and liberation of histamine were some of the views which were put forward. With our interest in the mucous barrier in relation to ulceration we reinvestigated the problem of cinchophen ulceration. A batch of dogs was fed with cinchophen (200 mg./kg.) for over 30 days. The gastric juice and the mucosa were investigated and the results obtained suggested a definite breaking of the mucous barrier directly. related to the formation of ulceration.

In our efforts to produce chronic experimental peptic ulceration in animals, we tried the feeding of large number of chemical compounds which were supposed to have a deleterious effect on the gastric mucosa and we noted that phenylbutazone (1,2diphenyl-4-butyl-3,5-pyrozolidinedione) was the drug of choice. This drug is used in rheumatoid arthritis and has been reported to reactivate healed peptic ulcers which led to haemorrhage and perforation in some patients. We, therefore, fed phenylbutazone to guinea-pigs in a dose of 100 mg./kg. body weight over a period of 30 days. This prolonged feeding caused well-defined deep chronic ulceration of the stomach. The ulceration was associated with a steady decrease of mucin in the gastric juice and depletion of mucin from mucous cells. The absence of an efficient mucous barrier associated with the corrosive action of free acidity led to ulceration histopathologically similar to that seen in man.

In the above experiments the point in which phenylbutazone ulceration in guinea-pigs differed from that of human beings was the multiplicity of ulcers. It was felt that possibly this may be due to the species differences. We, therefore, used dogs and fed them 100 mg./kg. body weight of phenylbutazone for a period of 118 days. The stomach and duodenum of dogs, which died or sacrificed, were studied. A deep single ulcer or rarely two ulcers histopathologically similar to that seen in man was present. The ulcer eroding all the gastric layers, except the serosa, with punched out and well-defined margins was present at the pyloric end of the stomach. The floor of the ulcer was covered with necrotic cell debris, underneath which strands of fibroblasts and infiltration with inflammatory cell was present. A complete perforation was observed in three dogs. One of the important findings was the significant lowering of the gastric mucin and depletion of mucin from gastric mucous cells. This, therefore, indicated that phenylbutazone or its metabolic products have a mucous barrier damaging effect either by inhibiting the formation of mucin or by destroying it as soon as it is formed. It may, therefore, be concluded that the damage of mucous barrier, associated with the corrosive action of free acid, is an important factor in the production of chronic peptic ulceration.

Experimental Peptic Ulceration with Unbalanced South Indian Diet and Its Relationship with Mucous Barrier

Experimental animals were kept on a protein deficient South Indian diet along with spices like capsicum of red variety. This led to complete depletion of epithelial gastric mucin, a damage of protective mucous barrier, accompanied by chronic ulceration of the glandular parts of the gastric mucosa [Roy, A. K., Singh, G. B. & Nityanand, S., Indian J. exp. Biol., 3 (1965), 203].

Therapy of Peptic Ulceration

On the basis of the above experiments we suggested that the stimulants which may stimulate mucous cells to secrete mucus without markedly stimulating peptic or parietal cells and having no ill effects on the mucosa of the stomach, may prove of value in the prevention of ulceration. With this in view, we investigated calcium, barium and sodium eugenates in the prevention of acute histamine induced peptic ulceration. A marked protection from histamine induced ulceration was noted with calcium eugenate and it was suggested that this may be due to the splitting of calcium from eugenol, whereby eugenol stimulated mucous secretion and calcium combined with hydrochloric acid to form calcium chloride which inhibited both the nervous and chemical types of gastric secretion and acted as an antispasmodic. Our investigations indicated that eugenol and its various salts in low concentrations employed have a value in the prevention of histamine induced ulceration.

Among the many vegetable mucins investigated. Brassica oleracea which possesses in its leaves glucouronic acid-like substances significantly prevented experimental ulceration. The prevention was directly related to the significant increase in the gastric mucin. The experimental ulcers healed completely within 120 hr. It has been suggested that the rapid healing of ulcers was due to the presence of mucin-like substances in the juice of B. oleracea var. capitata.

The present experiments open up a new and fruitful field of research in the therapy of peptic ulceration. It is suggested that a search for suitable mucins for use in the treatment of peptic ulcer may be made. The use of gastric mucous stimulants which may cause the direct stimulation of mucous cells and give an exaggerated physiological response ' a true reflexe defense ' in the form of mucus which neutralizes hyperacidity, depresses peptic activity and thereby prevents or heals ulceration may be investigated in human beings.

Conclusion

1. The studies present a concept of 'mucous barrier' in stomach in relation to peptic ulceration and show that the greater the degree of mucus secretion the lesser is the degree of acute ulceration. It has been shown that gastric mucin forms a barrier which prevents acute peptic ulceration. An efficient mucus secretion helps in the healing of acute ulceration.

2. Chronic peptic ulcer in dogs and guinea-pigs has been produced by phenylbutazone feeding which resembles the chronic peptic ulcer seen in man. Studies have also been made on cinchophen ulcer in dogs. It has been shown that the development of ulcer is related to the breakdown of mucous barrier.

3. In studies relating to the mechanism of the development of chronic ulcer in animals fed with unbalanced South Indian diet, it has been experimentally shown that the absence of an efficient

mucous barrier is responsible for the causation of ulceration.

4. In the therapy of peptic ulcer a concept of 'mucous stimulants' has been put forward which aims at the direct stimulation of mucous cells. A mucous stimulant which may provoke mucous cells to secrete mucus without stimulating peptic or parietal cells and having no ill effects on the mucosa of the stomach may be a step forward in the therapy of peptic ulceration.

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OR some time past our group has been interested in studying the functional importance of those regions of brain, which have now been shown to regulate various autonomic, visceral, endocrinal and behavioural functions of the individual. These brain regions are now collectively designated as the 'limbic system' of the brain. One of the most significant developments in modern neurology has been the gradual recognition of the existence of large areas in the brain which subserve autonomic functions, and which also form the structural background not only of emotional expression but of affective behaviour in the broadest sense. The development of our knowledge regarding the recognition of the functional significance of the autonomic nervous system, particularly in its bearing upon the phenomena of human behaviour, is a landmark in medical history.

Cortical and Sub-cortical Areas of Brain and Their Functions

More precise knowledge about the functional importance of the limbic system has been gained only in the last 2-3 decades. Most of the previous studies were directed to those areas of the brain which control the somatic activities of the body, simply because the resultant changes were easily observed and studied. It was known for a long time that in addition to the neocortical structures of the brain, which consciously regulate our somatic activities, there were vast cortical and sub-cortical areas whose functions were not clear. Only recently it has been realized that these areas form a common functional entity and are responsible mainly for the regulation of those activities of the body which help to maintain the homeostatic conditions. Their effects are achieved through changes in the activities of the autonomically innervated viscera, through changes in the secretory activity of glands including endocrines, as well as through affectively determined behaviour.

Langley in 1921, when he published his monograph on the autonomic nervous system, envisaged this system as a purely peripheral motor system innervating blood vessels and glands. He did not think of its functional relationship with other parts of the brain and spinal cord. The beginning of our more intimate knowledge of the part played by the forebrain in the integration of visceral functions came with experimental studies carried out on the hypothalamus, which for a long time was designated as the 'head ganglion' of the autonomic nervous system.

More recently, knowledge of the functional and anatomic interconnections between the hypothalamus and the other areas of the cerebrum has increased. Phylogenetic and cytoarchitectural studies, together with recent physiological investigations, have suggested that the cortical and subcortical structures included in the limbic system of the brain represent an early neural development involved in the higher control of autonomic nervous system and affectively determined behaviour.

Higher Nervous Mechanisms and Regulation of Body Activities

Much information has accumulated on the functions of the limbic system as a result of many studies carried out at various centres. My colleagues and I have also carried out a number of such studies.spread over the last 15 years, which have resulted in a better elucidation and appreciation of some of these higher nervous mechanisms regarding their regulation of various activities of the body which ultimately result in the maintenance of homeostatic conditions in the body. Although our activities have been directed towards working out the pattern of regulation by the limbic system of the brain of the various autonomic, visceral, endocrinal and behavioural activities of the body, regulation of one such function, i.e. feeding behaviour, which determines energy intake, has been more extensively studied by us.

It has been clearly demonstrated that the basic hunger and satiety mechanisms are located in two distinct areas of the hypothalamus. These have, therefore, been designated by us as the 'feeding centre' and the 'satiety centre'. The 'feeding centre' is the basic hunger mechanism which provides the urge to eat, and its activity is inhibited when the 'satiety centre' is activated after a meal has been taken. It has also been shown by us that the activation of the satiety centre is the result of afferents coming from the distended stomach, and as a result of increased utilization of glucose in the body. Over these hypothalamic mechanisms, the limbic structures exercise an influence which gives us discriminative selection of food and thus provides us with a 'discriminative appetite'. The neocortical influence, on the other hand, changes our feeding habits through ' conditioning ' and habit formation.

Similarly, in the hypothalamus there are two distinct mechanisms determining water intake. Anterior hypothalamic mechanism is sensitive to osmotic changes in the blood; on the other hand, in the latter hypothalamus a 'thirst centre' has been demonstrated experimentally.

Also, in the hypothalamus there are clearly demarcated areas which produce pressor as well as depressor effects on the cardiovascular and respiratory functions of the body. Some localization of these functions has also been shown in the limbic structures. Some pharmacological preparations, which influence the cardiovascular activities, possibly operate through these higher nervous levels.

Experimental studies conducted on the hypothalamus and the limbic regions also show marked influences on the motility as well as the secretory activity of the gastro-intestinal system. Disturbances

^{*}Based on the Dissertation by Dr B. K. Anand, Professor of Physiology, All-India Institute of Medical Sciences, New Delhi, on the occasion of the presentation of the Shanti Swarup Bhatnagar Memorial Award in Medicine for the year 1963, New Delhi, 29 July 1966.

of these nervous regions may lead to the production of ulcers in alimentary tract.

Other internal activities of the body which are innervated through the autonomic nerves are also influenced through experimental procedures applied to these nervous regions. Similarly, it has been shown that involvement of the limbic structures brings about changes in the functioning of liver, of kidneys, of various endocrine glands, and as a result of these produces changes in blood chemistry.

Limbic system along with hypothalamus has also been shown to take part in the elaboration of affective behaviour. Involvement of these structures change the social behaviour pattern of the animals, and lead to such abnormal actions: a rage reaction, fear complex, avoidance response, docility, ferocity, and so on. These experimental studies form the basis for neurosurgical treatment of some of the behavioural syndromes.

In summary, I may emphasize that neurophysiological and other experimental studies carried out on these regions of brain are giving us a fund of information which, when sorted out, will be of tremendous help in explaining clinical syndromes involving these regions. I have presented before you a varied picture of all kinds of functions which are represented in these areas, some of which have been demonstrated by our group. It may, however, be emphasized that our present knowledge about the functioning of this system is far from complete.

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Fabrication of Nuclear Fuels in India*

W7ITH the accelerating pace of industrial development and the consequent steep rise in power demands, the reserves of fossil fuels and hydro power would sooner or later prove inadequate. Further, there is a growing need today to conserve fossil fuels for non-energy uses, as they form an essential raw material for numerous chemical and metallurgical industries. In this context, the advent of nuclear power technology promises relief from dependence on conventional power sources. It has been estimated that by the turn of the century, nuclear power might well supply half of the world's energy requirements.

Among nuclear fuels of practical importance for the fission release of energy, uranium-235 is at present by far the most important, since it is the only one

to occur naturally. Plutonium-239 and uranium-233, on the other hand, are synthetic fuels, formed by the transmutation respectively of uranium-238 and thorium-232 by neutron irradiation in nuclear reactors. It is evident, therefore, that the first generation power reactors in an atomic energy programme have to be based on natural uranium unless a diffusion plant is established for the separation of uranium-235 from uranium-238. Nuclear power reactors, based on plutonium or uranium-233, can follow in the subsequent stages of the programme.

Whether it be a research reactor or a power reactor, the fuel loading has to be in the form of precisely dimensioned fuel elements, fabricated with scrupulous care. Only thereby can the 'reactivity' in the core be closely controlled, the heat efficiently abstracted, and the fission products safely contained. The performance of a reactor is thus largely dependent on the quality and the reliability of fuel elements and fuel element fabrication has become a highly specialized and sophisticated branch of

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reactor technology. It is needless to emphasize that self-sufficiency in making fuel elements is vital for the progress of any independent atomic energy programme. Illustrative of the diverse problems encountered in the fabrication of nuclear fuel elements, I propose to present in brief our experience with the fabrication of fuel elements of the CIRUS, a 40 MWt reactor, and Zerlina, a zero energy reactor for lattice investigations, and the development of technology for making fuel elements for power reactors of the type under construction in Rajasthan.

Fabrication of CIRUS Fuel Elements

The 40 MWt CIRUS is similar to the Canadian NRX reactor at Chalk River, and is fuelled with aluminium-clad natural uranium metal fuel elements. The reactor is moderated with heavy water and cooled with light water. The initial loading is ≈ 10 tonnes of uranium in the form of some 192 fuel elements. Each fuel element is about 10 m. long, the rolled uranium section (34.54 mm. in diam. $\times 3.124$ m. long) ' canned ' in 18 aluminium, constituting the central active zone. The fully assembled fuel element consists of 59 components, mostly in aluminium and stainless steel.

Early in the programme, the technology of fuel element fabrication was new to the country. The unusual size of the CIRUS fuel element core, the high standards of integrity demanded of it, and the complex metallurgical behaviour of uranium posed formidable problems in fabrication. Uranium metal (melting point, 1129°C.) exists in three allotropic modifications, the orthorhombic a-variety is stable up to 662°C. and the tetragonal β -variety between 662° and 769°C., above which it transforms into the body-centred cubic Y-form. On account of the volume changes that take place during the phase transformations, excursions into the β or γ region cannot be tolerated in reactor operation, and uranium temperatures have to be maintained within the range of alpha stability. The anisotropic structure of the α -phase, however, gives rise, under certain circumstances, to serious difficulties in the reactor. Under the influence of neutron irradiation, every single grain of *a*-uranium expands in the [010] direction and contracts in the [100] direction. If the orientation of the grains is random, the individual dimensional changes cancel out on the average. If 'textures' are present, however, pronounced macroscopic changes in shape occur leading to premature failure of the fuel elements. A principal problem in the fabrication of metallic fuel elements is, therefore, the selection of manufacturing methods which do not produce any harmful textures. Another problem closely linked to the anisotropic structure is the development of wrinkling and distortion. This type of damage is particularly apparent in uranium metal which has coarse and irregular grains. The individual crystallites grow in accordance with their orientation. After irradiation, a surface grain with an outward [010] direction takes the form of a peak, and one with an outward [100] direction that of a valley. This wrinkling cannot be altogether eliminated but can be greatly reduced by grain refining. The net result of the unusual irradiation behaviour of uranium is that unless the metal is fine grained and randomly oriented, it would be impossible to ensure its dimensional stability on irradiation. Improperly heat-treated uranium can grow manifold, thus leading to rupture of the 'can' and dispersal of fission products in the coolant.

In order to decide on the flow-sheet for fabrication, development work was, therefore, undertaken on small-scale equipment, although it was realized that some of the results, notably on heat treatment, would not be directly applicable to full-sized fuel cores. Before finalizing the flow-sheet, trial runs were hence carried out on a production scale during commissioning of the plant.

Nuclear grade uranium is produced at the Uranium Metal Plant, Trombay, in the form of 40 kg ingots, by calciothermic reduction and lately by magnesiothermic reduction of uranium tetrafluoride. Starting with these ingots, the main steps in fabrication are as under.

Melting and casting — The size selected for the cast billets which feed the rolling mill is 75-78 mm. diam. \times 910-920 mm. long. The melting and casting is carried out in a high vacuum induction furnace (≈ 3600 cycles/sec.) and the molten metal is bottom-poured into a graphite mould under vacuum. By this melting, residual slag and volatile impurities in the ingot are removed, but a certain amount of carbon passes from the graphite crucible into the melt. The pick-up of carbon is desirable because it results in grain refinement. On the other hand, excessive pick-up is harmful and in order, therefore, to control the pick-up, both the crucible and mould are coated with alumina. The density of the cast ingots is about 18.9 g./cc. (theoretical: 19.06 g./cc.) and the carbon content is maintained at about 500 p.p.m.

Alpha rolling of rods - The cast billets are rolled in the upper alpha range and during rolling the temperature is never allowed to fall below 450°C. The billets are heated in a horizontal immersion electrode salt-bath furnace in order to protect them from oxidation and to provide a salt film for protection during rolling. The rolls of the mill are provided with internal water cooling in order to minimize rise in temperature of uranium during rolling, as formation of the β -phase must be avoided. The sequence of rolling is oval pass design ending with round in the finishing stage. This was preferred to the Gothic design as roll contact with a greater part of the billet surface results in compression of the oxide skin. This greatly reduces the extent of oxidation and besides the rod remains under compression and, therefore, is less liable to crack. The reduction per pass is maintained in the range 4.8-11 per cent in order not to develop pronounced textures. The billet is frequently sprinkled with salt powder, between rolling passes, in order to maintain the protective film. The temperature of the rod is measured by contact pyrometers. Before further processing, the rolled rod is examined for any defects such as seams, cracks and pipes.

Heat treatment — The structure resulting from α -rolling does not conform to the ideal since it has preferred orientation, though the metal is fine

grained. A heat treatment to randomize the structure is, therefore, obligatory. For this purpose, the uranium rod is soaked in the beta range to a temperature of about 730° C. and quenched in water. This is achieved either by (i) heating the rolled rod in a vertical salt-bath furnace and quenching it subsequently in water, or by (ii) transverse-quenching through an induction coil in which the uranium rod attains the desired temperature as it is drawn through the coil and is spray-quenched in water as it emerges from it. It has been established by X-ray methods and thermal cycling tests that the rods thus heat treated are quite free from preferred grain orientation. The material is fine grained having a grain size of about 100 microns.

Machining — The rod is straightened on a roller straightener and machined on a centreless turner. Threads are machined on a lathe at either end and the rod finish-ground to the final dimensions on a centreless grinder. The machining of uranium is carried out using special carbide-tipped tools.

Canning and welding - The finished rod undergoes a series of cleaning operations such as degreasing in trichlorethylene, pickling in dilute nitric acid, spray-washing and drying. After final inspection, aluminium plugs are screwed on its two threaded ends. The rod is then lowered into a finned 1S aluminium tube (40-80 mil wall thickness) and ' canning ' carried out by drawing the assembly on a draw bench through a special die so as to provide a good mechanical bond between uranium and aluminium for better heat transfer. After drawing, the sheaths are cut to approximately 3 in. longer at either end of the end plugs and the end rolled over the end plugs. Finally, two outer aluminium plugs are screwed on to the inner plugs, one at each end, and the end closure effected by argon-arc welding.

Assembly of top and bottom components — After inspection of the components, welding of the top and bottom sub-assemblies is carried out under argon gas. The sub-assemblies together with the central uranium section are finally assembled into the 10 m. long finished fuel elements at the CIRUS site.

The first prototype fuel element was fabricated at Trombay in June 1959 and two fuel elements from the first batch were flown to Canada in October 1959 for irradiation testing in their NRX reactor. They behaved extremely well in dimensional stability under irradiation and were considered among the very best produced in Canada. They remained in the reactor close to 13 months and showed very little growth after use in the reactor. The CIRUS design provides for an elongation of 17.8 cm. in each fuel rod. One of the two rods from Trombay increased by only 0.25 cm. after an irradiation of 1840 megawatt days and the other by 1.5 cm. after an irradiation of 1620 megawatt days per tonne.

Regular production of CIRUS fuel elements started towards the end of 1959 and the Trombay fabricated fuel elements constituted half the initial fuel charge of CIRUS which attained criticality on 10 July 1960. The reactor is now entirely fuelled with Indian fabricated fuel elements, and their performance over the years, as replacement charges, has been as good as that of the Canadian fuel elements in NRX, if not better.

Fabrication of Zerlina Fuel Elements

India's third reactor, Zerlina, was designed, engineered and built by Indian engineers and scientists. It has aluminium-clad natural uranium metal fuel elements, and is moderated with heavy water. The reactor reached criticality for the first time on 14 January 1961 and its maximum design power level is 100 watts. Its core can be varied for conducting lattice investigations.

The fuel elements for Zerlina were fabricated at Trombay and the initial charge consisted of 3.7tonnes of uranium in the form of 80 fuel elements. The fuel elements are similar in design to the CIRUS fuel elements and comprise a rolled uranium rod, 35.6 mm. in diam. $\times 2.468$ m. long, canned in an aluminium tube, 1 mm. in wall thickness. The fabrication technology and control testing is similar to that for making the CIRUS fuel elements, except that end closure for 'canning' is carried out by fusion argon-arc welding. The full assembly is made up of 12 components, mostly in aluminium and stainless steel.

As Zerlina is a zero power reactor, the fuel elements are not under any severe strain and as a result the reactor is still operating on the first fuel charge. For lattice investigations, however, fuel cores have been occasionally changed. For such studies, special fuel elements were developed and fabricated. They included: (i) uranium metal fuel elements of different geometries clad in aluminium, and (ii) 19-rod cluster type uranium oxide fuel elements clad in aluminium.

Economics

The fuel fabrication facility at Trombay is in the nature of a pilot plant. The total initial investment in the plant was about Rs 50 lakhs, including a foreign exchange component of Rs 30 lakhs. The imported cost of the fuel elements of the type under fabrication would be about Rs 2.5 lakhs (pre-devaluation basis) per tonne, of which half is towards the cost of fabrication. The annual replacement requirements for CIRUS are some 15 tonnes of fuel elements from which it is evident that the entire foreign exchange cost of the plant had been met after less than two years of its operation. This is quite apart from the savings arising from the lower cost of indigenous fabrication.

Development of Power Reactor Fuel Elements

The fuel fabrication facility, apart from serving as a production unit for supplying fuel charges to the research reactors at Trombay, has also been a centre for the development of technology relating to power reactor fuel elements. During the Fourth Plan period, it is proposed to commission nuclear power stations with a total capacity of 1.2 million kilowatts. Work is already in progress on two nuclear power stations, one at Tarapur (Maharashtra) contracted to the International General Electric Co., USA, and the other Ranapratap Sagar, Rajasthan (RAPP), with the collaboration of the Atomic Energy of Canada Ltd. The Tarapur reactors will be of the boiling water type using slightly enriched uranium dioxide fuel, clad in zircalov-2. The Candu-type Ranapratap Sagar reactor will be fuelled with natural uranium dioxide, clad in zircaloy-2 and moderated and cooled with heavy water. While the entire initial fuel loading and all the structural core components of the Tarapur station will be supplied from the USA, the fabrication of fuel elements for periodic replacements at this station is planned indigenously. In the case of the Ranapratap Sagar station also, half the initial fuel charge and all the replacements are scheduled for indigenous production. For the other power reactors proposed, it is planned to carry out the entire fabrication of the fuel elements in the country.

Uranium dioxide has come to be widely accepted as a power reactor fuel in preference to uranium metal. The oxide has a high melting point ($\approx 2800^{\circ}$ C.) and an isotropic crystal structure; it does not undergo any phase changes on heating and cooling, and is dimensionally stable under prolonged irradiation. There is no significant swelling or distortion as the fission products are mostly retained within the fuel. Thus a burn-up of 9000 MWd/ tonne of uranium is expected from the Rajasthan reactor and a burn-up of 16,500 MWd/tonne from the Tarapur reactor.

The main problem in the fabrication of UO₂ fuel elements is the attainment of very high density, so as to accommodate the maximum number of fissile atoms in a given volume. Most of the development work on the production of natural UO2 pellets for RAPP-type reactors has already been completed at Trombay, and a sintered density better than 94 per cent theoretical, as specified, is routinely obtained. Details have been worked out for the setting up of a fuel fabrication facility with an annual capacity of 100 tonnes of contained UO2. In the flow-sheet thus developed for the industrial production of UO_2 pellets, UO_2 powder that will be supplied by the Uranium Oxide Plant will first be precompacted and then granulated into a free flowing powder for the compacting stage. The final compacting will be carried out in hydraulic/ mechanical presses employing tungsten carbidelined multi-cavity dies. The green pellets will be heated in hydrogen atmosphere to a temperature around 1650°C. to get sintered pellets of over 94 per cent of theoretical density. The pellets will then be surface- and end-ground to close tolerance. After final inspection, the pellets will be loaded into zircaloy tubing for fabrication into fuel assemblies.

The initial inventory for a 200 MWe RAPP-type reactor is 60 tonnes of natural uranium oxide (equivalent to 1.8 million pellets). The recurring annual requirement for fuel replacement per reactor will be 30 tonnes of finished UO_2 fuel which, if imported, is estimated to cost around Rs 100 lakhs.

The cladding of the UO, fuel will be with zircaloy-2, which offers the best combination of neutron economy, corrosion resistance and high temperature strength. For a 200 MWe reactor, the initial inventory of zircaloy is estimated at around 27 tonnes and the recurring annual requirements will be around 3 tonnes. For the Tarapur station, the recurring requirement of zircaloy components for replacement amounts to 6-7 tonnes per year. With the installation of 1.2 million kilowatts of nuclear power during the Fourth Plan period, the imported cost of zircaloy required for replacement purposes alone will be about Rs 185 lakhs per year. India has large reserves of the essential raw material for the production of zirconium metal - namely zircon from the Kerala and Madras beach sands and because of the large foreign exchange saving arising from indigenous production of the metal, it has been decided to set up a Zirconium Plant for the production of 50 tonnes of finished zircaloy components per year to meet the demands of the first line of reactors. Pilot plant production of zirconium metal has been achieved and development work on the complex technology of zirconium melting and zirconium tube extrusion is in an advanced stage.

Nuclear fuel fabrication has been a challenging experience to Indian metallurgists. The operations at Trombay have given the essential confidence and optimism for the projected atomic power programme.

Metallurgical Research & Development at the National Metallurgical Laboratory, Jamshedpur*

In relation to other sciences, Indian metallurgy has had a humble beginning. From a tiny embryo and small nucleus, Indian metallurgical research began to take concrete shape over two decades back, especially under the powerful stimulus of the World War II. Researches that attracted me related chiefly to the field service performance or rather the failure of war equipment, such as of armoured carriers and bullet-proof armour-plate.

Research facilities then were truly scanty and time targets militarily rigid, since the investigation results were to be immediately applied in the field. Nevertheless, the results were highly satisfactory in saving life and equipment — the intercrystalline cracking and failure of nickel-chromium-molybdenum alloy steel armour was checked. Related defence themes covering research investigations on deep drawing steel sheets, high tensile tyrebeading wire, silico-manganese spring steels, etc. — end-products then made in India under the stimulus of war emergency, usefully served the war effort.

Austenitic Grain Size Control of Steel

A peace-time subject of metallurgical research which has been my first love relates to 'austenitic grain size control of steel' introduced by me in India and actively pursued at the National Metallurgical Laboratory (NML) - it formed a major technical subject for our presentation and theme for discussion at the last International Symposium on 'Micro-Metallurgy' organized by NML. The real pleasure for a scientist lies in discarding his own favourite and pet theories. In formulating the aluminium solution theory among the hosts earlier advocated and while investigating it at length, I found it was unable to answer and satisfy some characteristics of grain growth inhibition. The results were published in one of the earliest monographic publications of the Council of Scientific & Industrial Research by me and one of my colleagues; the work was acclaimed in the overseas technical press as an excellent indication of the progress that is being made in India. Arising, however, over the untenability of the aluminium solution theory in explaining some of the typical characteristics of austenitic grain growth inhibition in steels and related aspects of abnormality in steels, my attention gradually veered towards the role of aluminium nitride in austenitic grain growth inhibition in steels and abnormality characteristics. Sustained research was carried out by me and my colleagues on these subjects, the results of which today find almost universal acceptance. The aluminium nitride theory has been able to explain the

characteristics of austenitic grain growth and its inhibition, 'abnormality' and 'abnormal' structures in steels. Our work has clearly provided an explanation for austenitic grain size control and abnormality in steel with its multi-pronged effects on other metallurgical characteristics, such as stabilization of steel, strain ageing effects, etc.

Substitute Alloys

Having had our first breakthrough, the tempo of work increased steadily and with improved research equipment and experimental facilities available at the growing NML, attention was directed towards other applied subjects of direct industrial importance. I always felt the urgent necessity directing Indian metallurgical researches of towards fields covering the development of substitute alloy steels and families of alloys and substitute metallurgical operations, etc. In thus defining metallurgical research projects and choosing the work relating to the development of substitute alloys, I felt that Indian metallurgical researches would thereby be distinctly project oriented (a theme then unheard of). It would also have a definite applied value and scope in industry and at the same time would place high premium on ingenuity in basic research as applied to development projects. An attendant advantage was that in doing so the scope of the basic research themes and applied projects was thus clearly defined and one was thereby led to specific channels embracing well-defined applied and industrial objectives, time targets and the means to be adopted to achieve them within the laboratory and outside in collaboration with industry.

India has practically no nickel, cobalt, tungsten, molybdenum, etc., and we do have some re-sources of zinc and copper. The work in respect of these metals was divided into two fields - one covering the development of substitute families of alloys in which the non-indigenous metals were to be totally replaced and the other to the development of partly substituted alloys by those resources which India did possess, such as chromium, manganese, aluminium, etc. Basic scientific data showed the potentiality of total replacement of indigenously scarce nickel in austenitic stainless steels by nitrogen. In much less time than expected, the nickel-free austenitic stainless steels developed at the NML after exhaustive research and pilot plant investigations and service testing were sent to almost all the leading metallurgical research laboratories of the world and confirmatory and appreciative reports were received.

Likewise, work on the replacement and substitution of nickel in other alloys and alloy steels, including high temperature creep resistant steels, was started and has been keenly pursued. Other research projects of applied interest and value to the industry initiated include the elimination

^{*}Based on the Dissertation by Dr B. R. Nijhawan, Director, National Metallurgical Laboratory, Jamshedpur, on the occasion of the presentation of the Shanti Swarup Bhatnagar Memorial Award in Engineering Sciences for the year 1964, New Delhi, 29 July 1966.

of nickel and cobalt in high temperature heating elements and alloys.

Parallel substitution studies related to the substitution of zinc by aluminium — the one metal in which India is rich. The process of aluminizing of steel was thus successfully developed and the highly commendable reports of the British Iron & Steel Research Association on the NML aluminized steel wire were a source of considerable satisfaction to me and my colleagues.

Foundry Sand and Bonding Materials

Another major field of activity related to the Indian foundry sands and bonding materials. An active research group was formed at NML to investigate Indian foundry sands and bonding materials on an all-India basis. The result was a valuable monograph on the subject.

Pilot Plants

It was in 1957-58 that I met and later came into close personal and professional contact with two outstanding scientists and acknowledged authorities in iron and steel research and industry. These were Sir Charles F. Goodeve, Director of the British Iron & Steel Research Association, and late Prof. I.P. Bardin, Vice-Academician, USSR Academy of Sciences. Their research laboratories and the different divisions were equipped with integrated and massive pilot plants operating round the clock on diverse metallurgical processes, which they had developed successfully on a laboratory scale. The pilot plants set up by their laboratories served to translate the results of their researches to industrial scale operation, establishing the economics of their processes, providing their metallurgical feasibility and yielding blueprints for putting up their industrial counterparts; in doing so they trained their workers as well. I was then advised by these two scientists to put up integrated pilot plants for batch and continuous operations on important metallurgical problems of interest to the mineral and metallurgical industries in India. We went all out to set up the pilot plants at NML with set time targets for completion. And today we can rightfully take pride in the integrated pilot plants established in the course of a few years, which rank among the best anywhere. The results of researches and pilot plant trials that have since flowed out of these pilot plants have given NML a high reputation in the metallurgical world. One pilot plant after another, some wholly designed and fabricated at NML, went into operation often ahead of schedule. The results of these pilot plant operations are there for the study of all interested and especially for the industry to scrutinize from the standpoint of technoeconomic implementation of the NML processes on a commercial scale. Some of these pilot plants are completely new and unknown this side of Suez, such as the low-shaft furnace pilot plant; the recently fitted light petroleum naphtha injection installation, wholly indigenously designed and fabricated, has indeed been pioneering and first of its kind anywhere.

The development of alternate processes of iron production with indigenous raw materials dispersed

in different parts of India has been a major field of my interest. Valuable contributions in this area by research workers in NML have put NML on the research map of the metallurgical world.

Intensive activity and systematic work in this field followed the installation of the low-shaft furnace pilot plant. Comprehensive reports were prepared on the smelting trials for iron production with regional raw materials and feasibility studies undertaken thereon for different States, such as Punjab, Andhra Pradesh, Maharashtra, Rajasthan, etc., as well as for Nepal. I have always advocated the establishment of small pig iron production plants regionally dispersed at optimum locations within the country, employing regional raw materials. The annual demand of foundry grade pig iron in India is currently estimated at about 2.5 million tonnes; the present supply of just over a million tonnes is chiefly met by blast furnaces of heavy integrated iron and steel complexes. The requirement of foundry pig iron will further increase at the end of the Fourth Five Year Plan to over 4 million tonnes. It has been rightly stated that to employ a giant iron blast furnace of hearth diameter of 25 ft and over for the production of foundry grades of iron would not be advisable on economic grounds. As such, to employ a giant iron blast furnace for the production of foundry grades of pig iron would be tantamount to producing a crude semi-finished product in a heavy integrated iron and steel plant instead of giving the same crude semi-finished product its logical steel end-products which will effectively ensure adequate returns on the heavy capital outlay. In many countries, different foundry grades of pig iron are produced in blast furnace with, say, a hearth diameter of around 15 ft or so. It would, therefore, be advisable to put in smaller hearth diameter blast furnace for the production of foundry grades of pig iron instead of utilizing giant hearth diameter blast furnace for foundry iron output. As is well known, the cost of production of foundry grades of pig iron is higher than that of basic pig iron used for steel-making; and any foundry iron made in a heavy integrated iron and steel complex would be at the expense of corresponding, if not greater, output of steel and its finished end-products, resulting in consequential unfavourable capital returns. In a few quarters, the economics of iron production in small-scale plants have been looked askance, but it is considered necessary to emphasize that each of the points raised can be most squarely dealt with. Further, the indigenous fabrication of a small iron blast furnace and its auxiliaries can be undertaken much more readily than a heavy integrated iron and steel plant. All these plants for foundry iron production in different parts of India hold great promise for Indian iron foundries in meeting in turn their obligations to the fast developing Indian engineering industries. This then has been the basic theme of mine which is now gaining ground - the small iron production plant in Orissa and its current triple . expansion represent the confidence of the industry in our researches in these fields and portrays what 'research for industry' can achieve and hold out for future collaborative enterprises.

Integrated Mineral Beneficiation Pilot Plant

The integrated mineral beneficiation pilot plant set up by NML is another fine example of what teamwork can achieve. The work at this pilot plant has been chiefly responsible for the implementation of the mineral beneficiation flow-sheets, agglomeration techniques and ore dressing and upgrading cycles developed at NML by the Indian steel plants. The Russians have fully accepted the NML developed flow-sheet for iron ore beneficiation and sintering of the Kiriburu iron ores to feed iron blast furnaces at Bokaro. Same is the exciting story of the researches carried out with the help of this pilot plant in respect of coastal plants in Goa, nonferrous industry, such as Khetri copper, etc.

Integrated Ferro-alloy Pilot Plant

The establishment of the integrated ferro-alloy pilot plant at NML has been another feather in our cap. The pilot plant results of the ferro-alloy production trials have not only met the urgent needs in part of the defence and ordnance plants during the war emergencies but also of metal industry in general, besides saving considerable foreign exchange through the development of indigenous technical 'know-how' for the smelting of pedigree series of specialized ferro-alloys employing indigenous raw materials. Other pilot plants successfully set up relate to production of electrolytic manganese and manganese dioxide, vacuum refining of zinc dross and production of magnesium from dolomite by silico-thermal reduction in vacuum.

Side-blown Pneumatic Basic Converter

A turning point came in my career when I visited Communist China in 1959 and studied their systems of research and industry in iron and steel metallurgical fields very closely. During my plant visits, I observed the Chinese methods of steelmaking, including pneumatic steel refining. On my return, I set up an active team on side-blown pneumatic basic converter steel-making process at NML. In my opinion, this process is of immense potential to India. My group has laboured hard in perfecting the technique of pneumatic iron refining in the basic side-blown converter at NML into an efficient and modern steel-making process. The process does not need any injection of tonnage high purity oxygen or oxy-fuel injection, or indeed any power to undertake the electric melting and steel refining requiring imported graphite electrodes and highly capital intensive plant and equipment. The entire plant and the side-blown basic lined converter for industrial steel production can be wholly and indigenously designed and fabricated, much the same way as the pilot plants have been set up by NML. The side-blown basic converter steel-making process is a major breakthrough and the results of our pilot plant operations will be implemented by the steel industry not only in India but also in other developing countries all over the world. The steel made by this process fully conforms to international standards in respect of nitrogen content and quality characteristics and other metallurgical criteria. The production costs are also lower than in other steel-making processes and the process can lend itself to making low, medium and high carbon steels as also low alloy steels, employing conventional cold steel scrap charges and will suit Indian conditions admirably. What I am advocating is the establishment of small iron and steel-making plants in different parts of India comprising small iron blast furnaces smelting regional raw materials for basic or/and foundry iron production. For steel-making, the molten basic iron will be fed directly from the small blast furnace through a metal mixer to the side-blown basic lined pneumatic steel-making converter. The molten steel can then be directly cast into finished steel castings or alternatively bottom-poured into a network of small ingots. These small ingots can be directly fed into the billet re-rolling mills without needing any blooming and breakdown mills costing massive capital outlay, including heavy foreign exchange. Thus the host of re-rollers and their rolling mills all over the country that are operating much below their normal or peak production capacities due to chronic shortages of home-made or imported steel billets can become wholly selfsufficient and fully productive, besides being independent of billet supplies to keep them going and preventing them from shutdowns.

Miscellaneous Researches

Other basic research and applied development problems that attracted me relate to the metallurgy of copper and the development of aluminium-based magnesium alloys for multi-engineering purposes, including wrought Al-Mg alloys treated with microadditions of rare earths that we possess so abundantly.

A process of using 'blue dust' iron ore fines for the production of high purity iron powder has been developed for the first time at NML involving an ingenious technique based on solid state reduction. When I initially proposed this research project, we were doubtful whether the high purity iron powder made from such abundant iron ore fines in the form of millions of tons of 'blue dust' available at all the Indian iron ore mines could yield such a high purity product entirely imported today. It is gratifying that our efforts met with an unexpectedly large measure of success.

Ionic Conductivity in Electrical Insulating Materials

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M ANY electrical insulating materials exhibit slight conductivity due to the presence of traces of free ions. The insulating capacities of these dielectric materials can thus be influenced by the incorporation of certain metal ions into them. This article considers in some detail the effect of the introduction of alkali and alkaline earth metal oxides on the electrical characteristics of two of the most important insulators finding extensive application in industry, viz. (i) glasses, in which ionic components are in the main composition of the substance; and (ii) papers, in which ionic components are only admixtures to the main non-ionic organic polymer, namely cellulose.

Glasses

One can directly observe the formation of electrolytic products in glass due to its transparency. When direct current is passed through glass, heated to diminish its viscosity and increase its conductivity, the cathode acquires typical branch-like deposits, dendrites, of the metals present in the glass.

Silica glass (composition, 100 per cent SiO₂) has a resistivity of approximately 1017 ohm-cm. at 200°C. Addition of components other than SiO₂, particularly the oxides of the alkali metals, causes a marked change in the resistivity of the silicate glass. This may be explained by the small size and consequently the high mobilities of the alkali metal ions^{1,2}. But of the two most important alkali metal ions, the sodium ion possesses greater mobility than the relatively bigger potassium ion. Therefore, from the point of view of insulating properties, the presence of sodium in the composition of a silicate (or boric) glass is more adverse than that of potassium (Fig. 1). Introduction of heavy oxides like BaO or PbO in an alkaline glass can increase its resistivity substantially. If there are two different oxides in the glass composition, its electrical insulation can be much higher than when the total oxide content of the glass is made up of one metal oxide only. This phenomenon is known as 'neutralization effect' or 'polyalkaline effect'. The neutralization effect in potassium-lithium glasses is much stronger than in potassium-sodium or sodium-lithium glasses (Fig. 2).

It is possible, in some cases, to improve the electrical insulating property of an alkaline glass by the introduction in it of other alkali metal oxides, provided the content of the first alkali metal oxide is not changed (suppression effect). Ionic admixtures, especially alkali metal ions, substantially increase the dielectric constant of glasses (Fig. 3). The changes in the power factor of glasses on the addition of varying amounts of the metallic oxides are brought out in Fig. 4.

The temperature dependence of power factor of glasses containing different ionic admixtures is, as a rule, very similar to corresponding temperature dependence of the specific conductivities.

It is possible to select an optimum composition of glass with high alkali metal content, and yet having high enough electrical insulation. The advantages of having alkali metals in the glass are many. Besides being cheap, alkali glasses have low softening temperatures and small variation of viscosity with temperature. These properties make them useful materials in technology.

Papers

It is obvious from Figs. 5 and 6 that both the resistivity and the dielectric loss angle of insulating papers (thickness, 8μ ; and density, 1.25 g./cm.³) depend on the type of cation admixture.

These papers were refined by treatment with weak hydrochloric acid and carefully washed with distilled water. After this treatment, the paper specimens were saturated with a cation by treatment with a suitable solution^{3,4}.

Figs. 5 and 6 show that bivalent cations have only a little influence on both resistivity and power factor of capacitor papers at temperatures above 0° C., but monovalent cations have considerable influence; but of the alkali metals investigated the one having the greatest influence is lithium followed by sodium and potassium. This order of influence is the same as in the case of glasses.

Of very great interest are data for power factor of papers at low temperatures. The dipole-radical temperature peak of the power factor is clearly raised due to introduction of cation into the composition of the paper (Fig. 7). This rise in the peak is greater, the greater the valency of the cation introduced and the greater its radius.

This can be explained as follows. In cellulose without cations, there are well-reinforced hydrogen bonds between the molecular chains. The hydrogen bonds hinder the oscillations of hydroxyl groups which create losses. When cations are introduced the distance between the molecular chains increases, thereby weakening the hydrogen bonds. The weakening of the hydrogen bonds facilitates the oscillations of the hydroxyl groups creating losses. Thus resistivity and power factor of insulating papers depend on the nature of the cations present.

Summary

The influence of alkali and alkaline earth metal addition to glasses and papers on their dielectric



Fig. 1 - Variation of resistivity (p) of silicate glasses with alkali metal oxide content at 200°C. Fig. 2 — Variation of resistivity (ρ) of silicate glasses with addition of mixtures of alkali metal oxides [(a) SiO₂-Na₂O-K₂O system; and (b) SiO₂-Li₂O-K₂O system. The numbers 40 and 27 on the curves refer to the total alkali oxide content in

the glass, in mole per cent]

Fig. 3 – Variation of dielectric constant (ϵ) of silicate glasses with alkali metal oxide content [ϵ values were measured at 50 c/s. and 20°C.]

Fig. 4 — Variation of power factor (tan δ) of boric glass with varying amounts of K₂O and Na₂O in the composition [The total alkali oxide content is 60 mole per cent; (60-at. % Na) will give the at. % of K]

Fig. 5 — Variation of resistivity (ρ) of capacitor paper with temperature [Curves: 1, paper with no ash; 2, paper with Mg²⁺ ions; and 3, paper with Na+ ions]

Fig. 6 — Variation of power factor (tan ϑ) of capacitor paper with temperature [Curves: 1, paper with no ash; 2, paper with K⁺ ions; 3, paper with Na⁺ ions; and 4, paper with Li⁺ ions]

Fig. 7 - Temperature variation of power factor of capacitor paper with additions of metal ions of different charge and size [tan 8 measured at 1000 c/s; Curves: 1, paper with no ash; 2, paper with Na⁺ ions; 3, paper with K⁺ ions; 4, paper with Ma⁺ ions; 3, paper with K⁺ ions; 4, paper with Ma²⁺ ions; and 5, paper with Ca²⁺ ions]

characteristics is discussed. Though the physical phenomena in these two insulators are different the effect of cation addition to them is very similar. Usually, the presence of alkali metal ions causes deleterious effects on the insulating capacity of glass and paper, but a judicious addition of the alkali metals can make them technologically more useful without largely impairing their electrical characteristics.

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Radioisotopes in Protein Metabolism*

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THE availability of labelled proteins has simplified the study of protein metabolism and extended knowledge in this field to an extent unforeseen before the availability of these labelled compounds. It is now possible to study, with the aid of radioisotope methods, the metabolic behaviour of individual proteins and hormones. In this paper, a survey of the preparation and uses of labelled proteins, and the application of radioisotope methods in studies on protein metabolism is presented.

Preparation of Labelled Proteins and Hormones

The preparation of a labelled protein should be undertaken with great care so that the labelled product is biochemically and biologically indistinguishable from the unlabelled protein. Only if the labelled protein is indistinguishable from the unlabelled one (except for radioactivity) can the data obtained by its use be extrapolated to represent the behaviour of unlabelled protein in an organism.

Choice of Label

The most suitable isotope is an isotope of iodine. The most commonly used isotope is ¹³¹I, but it is now felt that the effects of self-irradiation may perhaps be less by labelling with 125 I. The iodine atom enters the protein by oxidative iodination of tyrosine and once iodination is effected, the label remains firmly bound and is only liberated when the protein is catabolized.

Separation of Protein for Labelling

This should be done by salt precipitation or cellulose chromatography. Use of organic solvents for protein separation is undesirable as the separated protein becomes denatured during this process. Likewise contact with urea is also undesirable. For surface active proteins like fibrinogen contact with ion exchange resins should be avoided during separation or labelling.

Method of Labelling with ¹³¹I or ¹²⁵I

The most suitable method of labelling plasma protein is the iodine monochloride method¹. The chloramine-T method of Hunter and Greenwood² is not as suitable for plasma proteins but is the best method for labelling hormones.

Purification of the Labelled Protein or Hormone

Free ¹³¹I left in the reaction mixture after labelling can be removed by ion exchange with Amberlite IRA-400 resin (Cl) or by dialysis especially in the case of fibrinogen. With hormones not only must the free ¹³¹I be removed but also denatured hormone should be separated from undenatured labelled

hormone. This can be done effectively by adding normal plasma to the hormone when denatured products bind to the alpha globulin in the plasma and can be removed by cellulose chromatography. The undenatured hormone binds to the cellulose and can be subsequently eluted^{3,4}. Other methods are the use of Sephadex columns or starch gel electrophoresis2,5.

Special Labels for Proteins

For the measurement of gastrointestinal protein loss, albumin is labelled with 51Cr (ref. 6, 7) and protein absorption has been measured with ³H labelled albumin⁸. ³H label has also been used to prepare labelled enzymes9,10 and antibodies11.

Measurement of Protein Synthesis of Liver-synthesized Proteins

Albumin Synthesis

Determination of the synthetic rate of albumin by the liver - The method used was first employed by McFarlane¹². The principle of the method is given below.

The problem of measuring protein synthesis rates absolutely, as in nearly all tracer problems, is that of measuring the specific activities of intracellular precursor amino acids.

When ¹⁴CO₂ in the form of carbonate is injected into the system, it leads to protein labelling predominantly in the guanidine carbon of arginine (after entering the ornithine-citrulline-arginine cycle). Carbonate penetrates with great rapidity into cells, and condenses almost instantaneously in the liver with ammonia and ornithine to produce arginine. Because of the close metabolic relationship of arginine and urea, Swick suggested that urea emerging from the liver cell might be used as an indicator of the prevailing specific radioactivity of the guanidine carbon of intracellular arginine.

Thus synthetic rates depend essentially on a comparison of total activities and total masses of carbon incorporated into two products (urea and guanidine carbon of protein arginine) of the same precursor (guanidine carbon) of intracellular arginine in a given time. However, it is not the whole arginine molecule that contributes to the synthesis of urea but the guanidine ¹⁴C atom only.

Total ¹⁴ C counts in urea in time $t(Ku)$	Total counts in the $G^{-14}C$ of albumin in time $t(Ka)$
Urea synthesis in time t	Atoms of G-1 ² C incorporated in albumin in time t
or	1
Atoms of G-12C incorporated	

in albumin in time t

Ka Urea synthesis in time $t = \frac{\pi u}{Ku}$

Atoms of $G^{-12}C$ incorporated in albumin in time t $= (Ka/Ku) \times urea$ synthesized in time t

^{*}Based on Radioisotope techniques in the study of protein metabolism, Technical Report Series No. 45 (International Atomic Energy Agency, Vienna), 1965. Pp. 256. Price \$ 5.50.

- ∴ Atoms of G-1²C incorporated in albumin in 24 hr = (Ka/Ku) × urea synthesis in 24 hr using a suitable conversion factor for converting the mass of G-1²C in terms of albumin
 - Albumin synthesized in 24 hr = $16.3 \times 2.9 \times (Ka/Ku) \times$ urea synthesis in 24 hr
- A diagrammatic representation is given in Fig. 1.



URINE COLLECTED AND BOTH UREA EXCRETION AND IAC-ACTIVITY DETERMINED

Fig. 1 — Diagrammatic representation of the biological reactions involved in the measurement of protein synthesis. The two main collections made for measuring synthesis are urea excretion marked '1' and plasma marked '2'

Study of Protein Turnover

Turnover of plasma proteins is now a well-established procedure. It is usually done by using ¹³¹I or ¹²⁵I labelled protein. The labelled protein is injected intravenously and its distribution and degradation measured by observing simultaneously plasma activity, total body activity and the excretion of radioiodine in the urine after blocking the thyroid with Lugol's iodine or potassium iodide. To understand the principles involved in a study of the metabolism of plasma proteins, it would be illustrative to consider the plasma, total body and urinary activity after injecting ¹³¹I albumin (Fig. 2). The plasma activity declines rapidly during the first few days and then settles down to a single exponential. On the other hand, the total body activity declines more slowly and the slope of the total body activity is parallel to the final exponential of the plasma radioactivity. Therefore, the initial decline in plasma activity represents extravascular distribution since activity goes out of the circulation but not out of the body. The final exponential represents the excretion of radioiodine from catabolized protein and represents the catabolic rate. By subtracting the plasma activity from total body activity, the extravascular activity is obtained. From Fig. 2 it becomes apparent that the extravascular activity rapidly builds up and then declines at the rate of the plasma and total body activity.

Extravascular Pools

From these observations it is reasonable to assume that albumin exists in two sites, the plasma and an extravascular or several extravascular pools, which are in dynamic equilibrium with the plasma. It has now been experimentally demonstrated that there are two extravascular pools¹³. One exchanging rapidly about 3 times a day which is found in the



Fig. 2 — Representative curve of albumin turnover using radioiodinated human serum albumin (RIHSA)

liver and bowel and the other exchanging slowly about once in 2-3 days in the muscle and skin. The size of these pools can be measured by the equilibrium time method¹⁴ or by mathematical analysis¹⁵.

Albumin Catabolism

The ¹³¹I released by albumin catabolism is rapidly excreted in urine provided the thyroid is blocked as renal iodide excretion is very efficient. By relating the renal radioiodide excretion to the radioactivity in the plasma in extravascular sites or in the whole body, it is possible to arrive at an idea of the possible site of albumin catabolism. If the site is the plasma, then the ratio of urinary activity (QU)/plasma activity (QP) should remain constant from day to day, if it is the extravascular pool (QU)/extravascular activity (QE) should be constant and if albumin is catabolized generally in the whole body, then urinary activity (QU)/whole body (QE+P)activity should be constant. Experimental observation shows that the only QU/QP is constant whereas QU/QE and QU+P fall at first. Hence albumin degradation most probably occurs in the intravascular pool or in close relation to it¹⁶. From the above example it becomes apparent that from experimental observations of any ¹³¹I labelled protein the model of its distribution and degradation can he determined. However, synthesis is best measured by direct methods mentioned earlier.

Unsteady States and Computer Analysis

The above-mentioned methods of analysis by equilibrium time or mathematical methods are only applicable to steady states where catabolism = synthesis and pool masses remain constant. However, it is frequently desirable to study the effect of different diets, drugs and procedures on metabolism such as haemorrhage, high protein diet, infusions, etc., where an unsteady state occurs. In such cases, the best method is computer analysis with the aid of an analogue computer to simulate the experimental curves. By varying the input of different rate constants into the computer, it is possible to establish a model which fits the experimental situation. By doing this, the change in rate constants and pool masses can be derived from the computer. For details the interested reader is referred to a comprehensive article by Matthews¹⁷.

Protein Absorption and Gastrointestinal Loss

Protein Absorption

¹³¹I albumin was used to measure the absorption of proteins^{18,19}. However, detailed studies of the behaviour of ¹³¹I albumin during digestion showed that free ¹³¹I was liberated during this process²⁰ and hence it is unsuitable for the measurement of absorption. A more suitable method is the use of ³H labelled albumin⁸.

Gastrointestinal Protein Loss

Gordon²¹ introduced a new concept in the pathogenesis of hypoproteinaemia. He showed that a loss of protein into the bowel may result in hypoproteinaemia. The process is similar to the loss of protein in the urine in nephrotic syndrome. A measure of this loss can be useful in elucidating the cause of hypoproteinaemia in various gastrointestinal diseases. There are several ways of demonstrating gastrointestinal loss, but in all of them the principle is the same and is explained as follows. If a labelled protein is injected in a patient with gastrointestinal protein loss, it enters the bowel; but it is then digested and the digestion products reabsorbed so that measurement of faecal activity in such a patient would not be an index of amount of gastrointestinal protein loss. In order to measure gastrointestinal loss, some method is used to either prevent the reabsorption of the radioactive label²² or the protein is labelled with the isotope of an unabsorbable element like 51Cr, 67Cu or 95Nb (ref. 7, 23, 24). All methods so far used are semiquantitative and will only show whether the loss is excessive or not but cannot represent it as a percentage of the catabolic rate.

¹⁵N in the Study of Protein Metabolism

¹⁵N is a stable isotope of nitrogen and since nitrogen is an important constituent of proteins, this isotope has been found useful in studying some aspects of protein metabolism. The advantages are that it is not radioactive and can be used in children and it does not alter the properties of proteins. However, it is expensive and requires elaborate chemical processing to reduce all the nitrogen in the labelled protein to nitrogen gas which is then measured by mass spectrometry. Further, it is not as sensitive as a radioactive isotope as regards the lower limits of measurement are concerned.

The use of ¹⁵N has been useful in several fields of protein metabolism especially in reference to nutritional problems.

Utilization of Nitrogen in Forms other than Amino Acids or Proteins

It has been shown that ¹⁵N ammonium citrate can be utilized by the body and perhaps can replace non-essential amino acids^{25,26}. Such forms of nitrogen may be of value in the human diet. The retention of such nitrogen seems to be related to the protein intake and with low protein intake the retention is maximal²⁷. ¹⁵N could be profitably used to study the utilization of nitrogen from various sources and to relate it to the level of protein intake.

Protein Digestion and Absorption

The digestability and utilization of different proteins can be measured by this technique. This has been done by Crane and Neuberger²⁸⁻³⁰ who obtained interesting results. However, for the study of absorption alone the ¹⁵N technique is cumbersome and technique with labelled proteins are perhaps more easily carried out. However, the subsequent utilization of nitrogen could be best dealt with by using ¹⁵N.

Whole Body ¹⁵N Turnover

This has been done by Rittenberg and his coworkers^{27,31}; however, the body is composed of different proteins turning over at different rates and such an overall measurement is of little applicability except in general terms like the effect of endocrines^{32,33}, or protein and calorie intake³⁴.

Clinical Applications of Radioisotope Techniques

These applications are many and have been profitably used to study the mechanism of hypoalbuminaemia in gastrointestinal disease³⁵⁻⁴⁴, in liver disease^{39,45,46} and cance1⁴⁷⁻⁵⁰. The interested reader could refer to these articles.

Gamma globulin studies have been done in patients with a hypogamma-globulinaemia and the efficacy of different types of gamma globulins have been studied by these means⁵¹.

Application of Radioisotope Study of Malnutrition

These studies have been of great interest but have raised many new problems which need attention. The results so far obtained have shown that with malnutrition albumin is depleted to a greater extent from the extravascular compartment than the intravascular compartment⁵². However, gamma globulin level does not alter with malnutrition⁵³ and may even be elevated. Catabolism of albumin is reduced in cases of malnutrition but globulin turnover is unchanged⁵³. The effect of malnutrition on synthesis is less certain and a direct method like that of the one devised by McFarlane is necessary to assess the changes in synthesis. Although it is reasonable to suppose that synthesis should be reduced in malnutrition, there are little data based on objective evidence to prove this. It is especially important to study the effect of malnutrition on different plasma proteins because it is now known that globulin levels are not necessarily reduced in the same way as albumin with malnutrition.

Summary

The latest trends in the use of radioisotope techniques and ¹⁵N studies in protein metabolism are reviewed. The methods of labelling and measurement of protein synthesis and catabolism are described. Study of gastrointestinal protein loss and the methods used to measure it are summarized. Clinical application of these radioisotope techniques and the application of labelled protein studies in malnutrition are discussed.

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THE STRUCTURE OF LIE GROUPS by G. Hochschild (Holden-Day Inc., San Francisco), 1965. Pp. ix +230. Price \$ 10.95

The book under review contains much useful information and is well written. It can serve very well as a graduate text on Lie groups. As claimed by the author "it is addressed primarily to the student who wants to learn the basic techniques and results of Lie group theory quickly without having to weave his weave in and out of many books and papers' The author has successfully attempted to provide a systematic exposition and a shortcut to the most important general results on Lie groups, developing as needed the results from analysis, topology and algebra. In fact, Lie group theory proper is not introduced until Chapter VII. Only a very elementary knowledge of multilinear algebra, general topology, group theory and analysis is presupposed. Apart from that, the book is self-contained. The emphasis is laid on Lie algebras in dealing with the structural and representation theoretical features of Lie groups.

Chapter I deals with the elementary properties of locally compact topological groups. It contains the existence and uniqueness of Haar integral. Stone-Weierstrass theorem and Urysohn's lemma are also proved. The theory of compact groups and their representations form the contents of Chapter II wherein Peter-Weyl theorem and the Tannaka duality theorem are established. Chapter III contains a number of results on the structure of locally compact groups. The theories of covering spaces and covering groups form the contents of Chapter IV. Monodromy theorem is proved. Chapter V introduces the notion of power series and in it are included elementary properties that are needed in the sequel. In Chapter VI analytic manifolds are introduced and the properties of the analytic maps are given. Chapter VII covers the notion of Lie algebra of an analytic group. The main properties of the exponential map of the Lie algebra into the group are proved. Chapter VIII covers the properties of closed subgroups of analytic groups, homogeneous spaces and factor groups. The concept and the techniques of semi-direct product construction take care of Chapter IX. Chapter X is devoted to the study of Campbell-Hausdroff formula and its application to the theory of analytic groups.

Chapter XI deals with pure Lie algebra theory. Theorems of Lie, Engel and Cartan's solvability criterion are included. In Chapter XII, the result that every finite dimensional real Lie algebra is the Lie algebra of an analytic group is proved as an application of the results in Chapter XI and important results on normal analytic subgroups of simply connected analytic groups are obtained. The general structure of compact analytic groups is the concern of Chapter XIII. Chapter XIV is concerned again with the Lie algebra theory. Cartan sub-algebras have been discussed. The main result centres around the existence of real formsof compact type for the semi-simple complex Liealgebras. Chapter XV is an application of the results in Chapter XIV. The main results are concerned with maximal compact subgroups of Lie group. In Chapter XVI are given the results on the centres of analytic groups and on closures of analytic subgroups. Chapter XVII deals with complex analytic group has a finite dimensional faithful complex analytic representation has been proved. The universal complexifications of compact analytic groups have been characterized. Chapter XVIII is concerned with the faithful representation of analytic groups and the structure of linear analytic groups.

A few exercises are also given at the end of each chapter.

K. R. UNNI

NEW LIGHT ON SPACE AND TIME by Dewey B. Larson (North Pacific Publishers, Portland), 1965. Pp. 264. Price \$ 6.00

In this book the author presents a new theory of universe which he claims as the correct theory that explains all physical phenomena. The theory is based on two fundamental postulates. The first is that the physical universe is composed entirely of one component, space-time, existing in three dimensions, in discrete units and in two reciprocal forms, space and time. The second is that the geometry of the physical universe is Euclidean and its magnitudes are absolute. Moreover, it conforms to the relations of ordinary commutative mathematics. The author calls the system based on these postulates the reciprocal system. The theory puts forward the novel idea that all physical phenomena can be identified as different types of motion which he calls space-time relationship.

The book consists of seventeen chapters. The first three chapters constitute essentially a critique of existing physical theories, such as the special theory of relativity and quantum mechanics. The next chapter outlines some logical reasoning which leads to the fundamental postulates. In the subsequent chapters the author develops the consequences of the two postulates and identifies different types of space-time motion with physical objects and phenomena like the recession of galaxies, gravitation, atom, charge, magnetism and so on. Thus galactic recession is to be understood in terms of the progression of space which is analogous to the flow of time. A photon is an oscillating unit, an atom is a rotating photon whose inward motion is gravitation. Charge is one-dimensional rotational vibration, while magnetism is two-dimensional vibration. The author describes some of the astronomical applications and discusses the origin of cosmic rays.

The reviewer feels that the idea of space progression which is analogous to the idea of flow of time can be understood only in relation to objects which partake in such movement. By flow of time we simply mean that all physical objects evolve in an irreversible manner from past to future. Similarly, physical objects change space location and no meaning can be given to the change of points cf space as such. The magnitude of rotational motion is said to exceed that of progression. It seems that this asserts the existence of velocity greater than that of light. The author has derived inverse square law of gravitation but he does not explain the three crucial tests of general relativity. The book explains everything in a qualitative manner and it seems that detailed mathematical treatment of some physical phenomena could have made the theory more convincing.

S. R. Roy

PROBLEMS IN PARTICLE PHYSICS by A. N. Kamal (McGraw-Hill Book Co. Inc., New York), 1966. Pp. vii+126. Price 38s.

It is generally agreed that for a sharp understanding of physics, students should work out large number of problems; yet, not enough literature of this sort exists in elementary particle physics. Naturally, this book is bound to be well received by the students of particle physics.

Most of the time, class-room lectures emphasize the basic and the general so that a book of problems such as this which brings out precision will be a very desirable supplement.

The choice of the problems is good and clearly meant to illuminate the workings of the general principles. There is some room for improvement towards including more incisive problems and dropping out the obvious ones.

The subject matter covered is almost all of particle physics except the dispersion theoretic S-matrix approach and the SU_3 and group theoretic approach. The omission of the S-matrix approach is quite understandable and is consistent with the spirit of the book. However, no book on particle physics can afford to ignore SU_3 symmetry. This is a great shortcoming of the present book.

Gyan Mohan

TRANSISTOR CIRCUITS by K. W. Cattermole (Gordon & Breach Science Publishers, New York), Second

Edition, 1965. Pp. xv+470. Price \$ 14.50 Solid state devices in general and transistors in particular have attained such a high degree of importance in modern electronics and allied sciences that practically any book published on this subject would receive some attention of a person actively engaged in this field. Though the interests of the readers in this subject are of a comparatively diverse nature, there is a fairly large class of readers who have acquired sufficient background in the physical sciences and are interested in the principles underlying the operation of a transistor as a device as well as the mechanism of its operation as a basic circuit element. To this end, the second edition of the book under review would be an extremely useful treatise on this interesting and important subject.

Though the treatment is elementary, it is not at all superficial and makes a very interesting first reading because of the continuity of presentation and lucidity of expression.

The new edition includes some important aspects of a novel and useful treatment, such as the inclusion of internal feedback in a transistor as one of the important properties to be taken into account in a circuit configuration. This along with the switching properties of a transistor are adequately stressed in the book.

The chapters on the 'Electrical properties of transistors' including the treatment on breakdown mechanisms, 'High frequency amplifiers', 'Counting timing and logic' and 'Negative resistance' are particularly well presented and will be very useful to a beginner as well as to a circuit engineer from the point of view of understanding the basic physical concepts underlying the transistor circuit operation. Another special feature of the book is an exhaustive bibliography given chapterwise at the end of the book, as it contains references of the latest publications available.

Apart from serving the needs of a technical beginner, the book can be recommended as one of the text-books for postgraduate classes leading to a degree in physics or electronics in India.

G. N. ACHARYA

Accélérateurs CIRCULAIRES DE PARTICULES by Henri Bruck (Institut National des Sciences et Techniques nucléaires, Saclay), 1966. Pp. xii+358. Price 60 fr

The present monograph, one in the series of Nuclear Science and Technique Library, is an introduction to the theory of the circular accelerators. Since the discovery of the cyclotron, the enormous development in the physics of the accelerators is not only due to the precision engineering skill but the results of a good deal of theoretical research are also responsible for the same. The purpose of the book has been to introduce from the basic principles, the rigorous theories underlying the principles on which the different cyclic accelerators work.

This book will be very useful to readers interested in the theory of accelerators or who contemplate to design one for a laboratory.

In the introduction, the author has described the general principles of the circular accelerators of various types, which include both electron and ion accelerating machines. The problems of focusing associated with these machines are so important that the present evolution of the accelerators is mostly due to the solution and improvement in focusing of the charged particles with a magnetic field.

In Part 1, the author has treated the problem of focusing of charged particles in a constant gradient sector magnetic field. In Part 2, non-linear oscillations and stability conditions with AG synchrotrons are discussed. For convenience of the readers matrix calculus and Hill's equation have been introduced, so that later chapters of this part become easily intelligible.

Part 3 is important as regards the operation of a circular accelerator. In this part, instability of the beam due to the non-alignment of the field and error in the field index have been discussed. These imperfection resonances are treated explicitly from the theoretical point of view. Linear and non-linear coupled resonances have also been discussed. The last chapter of this part is a good review of the effect of the elastic scattering of fast protons with the residual gas of the chamber. This chapter will be helpful for a quantitative estimation of the effect of the vacuum condition for a favourable operation of the machine.

In Part 4, the proper acceleration mechanism is discussed and phase oscillations, momentum compaction, adiabatic damping of oscillations are considered.

The next part is devoted to the electron dynamics and acceleration of electrons to high energies and in the concluding part the author has treated the theories of the high intensity machines, including the latest developments in the accelerator techniques.

The present monograph will be a good supplement to the few books on accelerators previously published and an English translation of the same will be welcomed by a broader section of readers.

S. B. KARMOHAPATRO

FLUIDIZATION AND RELATED PROCESSES — A SYMPOSIUM (Council of Scientific & Industrial Research, New Delhi), 1966. Pp. xi+271. Price Rs 24; 48s.; \$ 8.00

This compilation presents a mixed fare in topics and quality. Fluidization has, by now, attained sufficient maturity. Its dilution by some topics, however analogous they be in certain mechanistic aspects, is unnecessary even though such 'related' papers may have their own merits. It is earnestly hoped that future symposia will be more selective.

The indigenous activities on varied facets of fluidization are, however, encouraging. Section four on heat transfer particularly draws one's attention. Rao and Murthi's papers on heat transfer in circular tubes and in liquid-solid batch fluidization by the Andhra University team are worth noting. The other two papers in this section include useful data. Oversights, such as undefined velocity for curve 5 of Fig. 3 on page 157, are obviously avoidable.

Section five is mostly devoted to application of fluidization to inorganic and organic processes. Studies on toluene oxidation by Kumar *et al.* illustrate one mode of kinetic analysis. Lakshmanan *et al.*'s work should be a useful addition to the increasing literature on ilmenite chlorination. The Jealgora team's data on ammoniation of coal should come handy for enhancing indigenous fertilizer production. The fifth paper in this section could have been aligned after the sixth in section two, though as a rather poor companion to the latter.

Zenz's paper in section two is thought-provoking. Bhatt and Gopalkrishna, with their respective teams, have offered good material.

Fluidized-bed drying review in section three is helpful to the designer and researcher. Results on the iron oxide-hydrogen sulphide system can find practical applications. More activity in fluidized mass transfer could be useful. Absence of reports on discussions is an important lacuna. These often can be more stimulating than the parent material and are included in all good proceedings. Use of standard symbols and notations and their comprehensive presentation could have been a space-saver.

The get-up and printing are quite good. The reviewer, however, wonders whether the price is compatible with the contents.

M. U. PAI

THERMOANALYTICAL METHODS OF INVESTIGATION by Paul D. Garn (Academic Press Inc., New York), 1965. Pp. xvi+606. Price \$ 19.50

Differential thermal analysis and thermogravimetric analysis have been extensively employed to study the thermal behaviour of materials under continuous heat treatment. Although considerable amount of literature has grown recently covering this field, the treatment has been mostly qualitative. The quantitative evaluation of their analytical results is rather difficult owing to the large number of parameters involved in the process. As a result, a system studied by different workers has been observed to give results which are not always identical.

It is refreshing to find that a detailed and critical examination of the experimental methods and results reported in literature has been made by the author to evaluate the potential uses and limitations of thermoanalytical methods. The following fields can be included under this heading: (1) Differential thermal analysis, (2) Thermogravimetric analysis, (3) Dilatometry, (4) Microscopy, (5) X-ray diffraction, (6) Calorimetry, (7) Conductivity, (8) Effluence analysis, (9) Differential calorimetry, (10) Dielectric properties, thermoelectrice.m.f.ormagnetic properties.

The first two topics have been treated exhaustively in the book containing 17 chapters covering 530 pages. The chapter on apparatus design gives very useful tips for consultation and selection of commercial gadgets to suit the purpose. The book is complete with references to current literature, calibration data and author and subject index. The book will be a very valuable addition to every laboratory engaged in thermoanalytical investigations.

A.R.V.

METALLURGICAL SOCIETY CONFERENCE: Vol. 28— PRECIPITATION FROM IRON-BASE ALLOYS edited by G. R. Speich & J. B. Clark (Gordon & Breach Science Publishers, New York), 1965. Pp. vii+ 412. Price \$ 8.50 (paper); \$ 21.00 (cloth)

This publication, covering the proceedings of the symposium 'Precipitation from Iron-base on Alloys', sponsored by the Metallurgical Society of AIME, represents the current status of several important basic metallurgical research themes relating to quench-ageing in C-Mn-C-N- alloys, precipitation from substitutional ferritic, martensitic and austenitic iron-base alloys, dispersion hardening effects in iron, tempering of martensite. effects of precipitated particles on mechanical and metallurgical properties of iron-base alloys, etc. Research interest in these important fields has recently been intensified by the introduction of transmission electron microscopy enabling the direct observation of the dislocations and precipitation and their conjoint interactions in the elucidation of relevant mechanism and kinetics of precipitation. Applied technological interest in these basic research themes relates to the development of precipitation hardening, mar-ageing steels exhibiting excellent strength and ductility. The applications of such fundamental research results have further increased in the wake of increasingly stringent demands for superior alloys based on latest thermo-mechanical treatment techniques.

The publication is superb in presenting an assessment of the overall state of knowledge in metallurgical fields of solid state phase transformations precipitation phenomena which are vis-à-vis remarkably complex and varied. It is often equally important to appreciate realistically the current status and state of affairs than to attempt explaining away in the mushrooming technical literature, the almost bewildering and complex variety of possible and actual combinations of factors governing the type, kinetics and morphology of the precipitation in complex alloys. This then is exactly what this publication brings out in refreshing clarity in putting across in proper perspective the valid explanations for innumerable observations on precipitation systems which at best amount to wishful predictions, while academically promoting an understanding of the subject. The subject is nevertheless fascinating, presented in an equally fascinating book. The editors are to be complimented for providing to the research metallurgists, theoretical physicists and applied technologists vast research data and significant scope for metallurgical probes, studies and applications currently heightened by improved research equipment and techniques and last but not the least by equally heightened demands on 'better and still better alloys' from the metallurgical back-room boys.

B. R. NIJHAWAN

SOUND CONTROL AND THERMAL INSULATION OF BUILDINGS by Paul Dunham Close (Reinhold Publishing Corp., New York), 1966. Pp. vii+ 502. Price \$ 17.00

Sound control and thermal insulation of buildings are both of major importance in building design. Since there is little common between the two, these are treated in separate chapters. The book contains explanation of the fundamentals, treatment of the factors involved in noise and heat transmission and discussion of the latest effective techniques of noise abatement, and heat control.

Besides these, the book includes a large volume of physical data on building materials and other essential design information enabling application of the products in these two major areas of building design. The treatment of the book is systematic and elegant. Complicated formulae and theory have been avoided as far as possible.

After a brief introduction to the subjects of sound control and thermal insulation, the author devotes a chapter on the fundamentals of sound. The origin of sound transmission class (STC), leading to rating of the insulation of partition walls and noise criteria curves leading to design noise levels are briefly given. Chapter 4 deals with auditorium acoustics involving good hearing conditions for speech and music. The next chapter is on noise quieting in office and industrial buildings, schools, hospitals and other types of buildings. Effective noise reduction, i.e. reduction in loudness, SPL and reverberation in an office caused by the acoustical treatment of the ceiling is worked out as an example of a typical design.

Sound absorption data for a large number of acoustical materials produced by the factories in USA together with their specifications, mounting condition and NRC values are given in Chapter 6. These values are required both for the choice of the material and for working out the design.

Effective noise reduction emerges from two measures: (1) adequate sound insulation of the partition walls and (2) proper impact noise insulation of floors and ceilings. The insulation at various audio frequencies provided by a particular type of wall or partition may be known by the sound transmission class (STC) rating number given in tables of Chapter 7. Similarly, isolation of structure-borne noise by floors and ceiling may be obtained from the FHA impact noise rating (INR) number. It is believed that impact noise transmission through a floor is also dependent on the type of source noise. As such, these rating numbers, based on the tests with the ISO impacting machine are not to be treated as final. Artifices designed to isolate machines from their foundation attenuating thereby transmission of vibration to the floor form the topic of Chapter 8. Details of isolation of the units that bridge the path of structure-borne sound in homes, apartments, hotels and institutions are also given.

The thermal insulation section includes a discussion of the fundamentals of insulation and the advantages desired from the use of thermal insulating materials. Thermal data for a large volume of commercially available products, including the method of their application, are given. Information and data are included on the methods of calculating heating and cooling loads. Insulation causes reduction in plant size, a capital saving as also a saving in fuel expenses. The economics of thermal insulation, an important factor in air-conditioning, is discussed in a lucid style.

In short, it is an extremely useful book, rich with essential design data and product information on sound and heat control.

N. K. D. CHOUDHURY

CROP ECOLOGIC SURVEY IN WEST AFRICA: Vol. 2 — ATLAS by J. Papadakis (FAO, Rome), 1965. 24 maps and 3 tables. Price 25s.

This survey covers the West African States of Liberia, Ivory Coast, Ghana, Togo, Dahomey and Nigeria. The classification of climatic regions used here is based upon a widely used system designed to show the similarities and differences between the climates of the various areas of the world. The main climates met with in the region covered by this Atlas are: Humid Semi-hot Equatorial (forest belt), Dry Semi-hot Equatorial (coastal savanah belt), Hot Equatorial-Tropical, Semi-arid Equatorial-Tropical and Tierra Templada (frostless highlands). Under each of these main types of climates several subtypes are to be found. The highlands and the coastal savannah belt together include a very minor part of the area dealt with by the Atlas.

Map 1 shows the division of the entire area into main climates while the subtypes are shown by classification numbers given at appropriate places within each main climate. Then there are separate maps to show the various climatic factors such as minimum and maximum temperatures, annual rainfall and potential evapotranspiration, beginning and end of humid and dry seasons, rainfall surplus, and drought stress. Map 9 shows the soil regions.

The most interesting portions of the Atlas are Maps 10-24. Map 10 demarcates the various crop ecologic regions summarizing for each climatic type and subtype the data given in the previous maps and listing at the same time the crops that are grown there or can be grown there under the prevailing climatic and soil conditions. Map 11 gives the natural vegetation regions. Each of the succeeding maps, from Map 12 to Map 24, deals with the ecologic regions of individual crops, beginning with regions where the crop is very successful or where it can be grown with comparative ease to areas where the crop can only be cultivated under some serious ecologic handicap or where the conditions are more or less inadequate for its cultivation. The crops so treated here are the oil palm (*Elaeis guineensis*), cocoa, coconut, rubber, rice, maize, sorghum, millet, groundnut, cotton, yams and cassava. Finally, there is a map of forage resources giving for each region the actual resources as well as the possibilities.

Following the maps, there are $\hat{3}$ tables extending over some 16 pages, Table 2 covering 14 of these. Table 1 gives statistical data for each country with respect to geographical area, population, area and production under each crop, and number of livestock. Table 2 gives climatic data for a number of locations in each of the countries covered. Table 3 gives the homoclimates, i.e. places with the same climate in West Africa and the rest of the world. It is interesting to find that Calcutta is homoclimatic with areas of West Africa where the oil palm is successful; similarly, the Nicobar Island seems to be suited for cultivation of cocoa.

The Atlas is not paginated and neither is there a contents page or index so that if anyone wants to find out the scope of the Atlas or locate any particular map or table he will have to thumb through the pages till he comes to what he wants. This absence of pagination may also possibly have led to production of some imperfect or incomplete copies of the Atlas and, in fact, the copy supplied for review happens to be one such. Not all places for which data are provided in Table 2 are, perhaps, to be found in the map because of the six or seven places checked at random, one could not be found.

An Atlas like the one under review is a great boon to all those who are concerned with the problems of agricultural progress of countries in developing areas like West Africa. Administrators, economists and development officers of these countries can now plan on a scientific basis the extension of suitable crops to the various areas whose full potentialities might not have been exploited properly so far due to lack of scientific crop ecological data and the present Atlas fills the lacuna in this respect.

R. S. CHAKRAVARTHY

PUBLICATIONS RECEIVED

- FATTY ACIDS INDUSTRY, TECHNOLOGY AND RE-SEARCH IN INDIA, Proceedings of the Seminar held from 10 to 12 February 1965 (Regional Research Laboratory, Hyderabad), 1966. Pp. viii +89. Price Rs 5.00
- INTRODUCTION TO MOLECULAR ORBITAL THEORY by Arno Liberles (Holt, Rinehart & Winston Inc., New York; *Distributors in India*: India Book House, Bombay), 1966. Pp. ix+198. Price \$5.95
- INTRODUCTION TO ELECTRICAL CIRCUIT ANALYSIS by Robert C. Carter (Holt, Rinehart & Winston Inc., New York; *Distributors in India*: India Book House, Bombay), 1966. Pp. xii+500. Price \$ 9.95
- ENGINEERING RADIATION HEAT TRANSFER by J. A. Wiebelt (Holt, Rinehart & Winston Inc., New York; *Distributors in India*: India Book House, Bombay), 1966. Pp. ix+278. Price \$ 9.50
- QUANTUM MECHANICS by A. A. Sokolov, Y. M. Loskutov & I. M. Ternov; translated by Scripta Technica (Holt, Rinehart & Winston Inc., New York; Distributors in India: India Book House Bombay), 1966. Pp. xix+537. Price \$ 11.00
- INDIAN FOSSIL PTERIDOPHYTES, Botanical Monographs No. 4, by K. R. Surange (Council of Scientific & Industrial Research, New Delhi), 1966. Pp. 209. Price Rs 23.00; 46s.; \$ 8.00
- VETERINARY MICROBIOLOGY by K. C. Mahanta (Asia Publishing House, Bombay), 1966. Pp. viii +271. Price Rs 14.00
- HIGH RESOLUTION NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY by J. W. Emsley, J. Feeney & L. H. Sutcliffe (Pergamon Press Ltd, Oxford), Vol. 1: 1965. Pp. 1+664. Price £ 5.5s.; Vol. 2: 1966. Pp. lii+665-1154. Price £ 5.5s.
 CONTINUUM MECHANICS: I — THE MECHANICAL
- CONTINUUM MECHANICS: I THE MECHANICAL FOUNDATIONS OF ELASTICITY AND FLUID DYNA-MICS by C. Truesdell (Gordon & Breach Science Publishers, New York), 1966. Pp. xvi+218. Price \$ 7.50
- PARTICLES IN THE ATMOSPHERE AND SPACE by Richard D. Cadle (Reinhold Publishing Corp., New York), 1966. Pp. viii+226. Price \$ 10.00

Pictograms of molecular orbital densities

An entirely automatic method of directly displaying the contours of the molecular orbitals and total molecular densities in a number of diatomic gases has been reported by Arnold C. Wahl in an article in a recent issue of Science [151 (1966), 961]. Besides their teaching value to students of quantum mechanics at a not too advanced level, these contour diagrams will be useful in stimulating thought about chemical binding, steric hindrance and bonding and antibonding orbitals, and provide a correct and more complete pic-ture of the shell model of which only a rudimentary conception, based primarily on hydrogen atom wave function, exists now.

Though the 'shell model'. introduced by Mulliken and Hund. was very useful in interpreting the structure of molecules qualitatively, its quantitative 'application and accuracy remained very limited because of the formidable amount of mathematical computation involved. The use of modern versatile electronic computer mitigated the computational difficulties and made the problem tractable. However, if the advances and refinement of this model can only be described in complex mathematical language or vast mass of not ordinarily understood numerical tables, the value of the model is still limited. It is here that the new method has a visual demonstrative value which assists in the comprehension and visualization of the fundamental concepts even by nonspecialists.

A CDC 3600 computer with an on-line DD 80 plotter was programmed for automatically hunting and plotting a given set of linear combination of molecular orbitals φ_i in the expansion form for a number of diatomic molecules. The orbital density and total density contours were generated utilizing two separate expressions comprising linear combinations of symmetry expansion functions consisting of chieffy parameters like the symmetry basis functions χ_{plac} and the orbital coefficient C_{iph} . Using the equation for deriving the molecular orbital

NOTES & NEWS

contour, a contour value was found and a contour line was hunted out by proceeding along the tangent until the contour was relocated within 1 per cent. By successively repeating this process, the entire contour was traced out. Straight line segments were then plotted between adjacent points, thus yielding as computer time exposures smooth curves. For obtaining the total density contours, the relevant expression giving the sum of the densities of all shells making up the molecule and its derivatives was used. The input to the programme consisted of values of $\chi_{p\lambda\alpha}$, $C_{ip\lambda}$, the internuclear distance R, a series of the contour values desired with the associated thresholds and finally the physical scale in which diagrams are to be plotted. The output consisted of 35 mm. negative films of the required diagrams.

The contour diagrams obtained clearly bring out the differences between the different shells of the same molecule as the differences in the values of electronic density in corresponding regions of space and in the overall pattern of contours. The difference between the same shells in different molecules is also depicted by these pictograms. The completely automatic programmes make it easy to visually analyse a large amount of data which hitherto lie as mere calculations. The new tool will best be used for studies, now in progress, of interatomic forces and the formation of the chemical bond, in displaying the changes occurring in electronic charge density as a molecule forms. In a study of molecular ionization these programmes are being used to illustrate directly changes in the molecular charge distribution resulting from electron removal. In theore-tical work, a pictorial display of configuration mixing is in progress which provides a physical picture of wave function improvements and electron correlation as produced by added optimal configurations.

Very high precision X-ray diffraction

Precision of the order of 1 in 10,000,000 in the measurement of X-ray diffraction angles has been achieved by the use of a specially designed instrument called the 'automatic precision X-ray goniometer', developed at the Metallurgy Division of the Atomic Energy Research Establishment, Harwell, Berkshire. Such high precision in the measurements has enabled the measurement of the coefficient of thermal expansion of crystals over a temperature range of even 1°C.

In the goniometer designed, the crystal is fitted to a holder attached to a gear shaft and the angles are measured by counting pulses given to a stepping motor connected to a worm and gear system coupled to the gear shaft. There is a closed error loop around the gear so that the sum of the errors is zero. When applied to problems of diffraction, the method consists in measuring the angle between the reflecting positions of the crystal, under which conditions errors associated with measurements of the diffracted beam (eccentricity of specimen, absorption, and zero error) do not occur. At the degree of precision aimed at there is a further systematic error due to the fact that the plane of diffraction may not be exactly parallel to the plane of measurement, so that the angle measured is only a projec-tion of the true angle. A simple procedure is followed by which the non-planar conditions introduced by a collimator tilt of small but unknown magnitude can be tolerated and this procedure at the same time adjusts the tilt of the crystal to the optimum value. According to the pro-cedure, the crystal is merely set on the side of a diffraction peak, and its tilt is varied until the maximum intensity occurs - such conditions result in maximum angle being obtained. Even with a collimator tilt of 10 min. at a Bragg angle of 80°, this procedure

introduces an error of only 0.25 sec. in the measured angle which is equivalent to an error of 1 in 10,000,000 in the crystal lattice constant. The instrument is maintained in a thermostatically controlled enclosure and manipulated by remote control.

The fact that the procedure can be automatically carried out makes it possible to feed the results to a computer to get the profile of the diffraction peak, so that small changes of position or shape can be properly described. The high sensitivity obtained by this method can be applied to experiments where changes of dimension or angle are normally measured macroscopically [Nature, Lond., **210** (1966), 720].

A film model for ethylene dichloride formation

A general model for the reaction of two gases in a liquid medium has been proposed, with particular reference to the formation of ethylene dichloride by simultaneous absorption and reaction of ethylene and chlorine in liquid ethylene dichloride [Industr. engng Chem. (Fundamentals), 5 (1966), 184].

According to this model chlorine and ethylene dissolve separately in ethylene dichloride; ethylene diffuses through the liquid film to meet chlorine diffusing in the opposite direction. The reaction zone moves away from the gasliquid interface, and within a very short time reaches an equilibrium position. As the reaction is very fast, the bulk concentration of chlorine and the equilibrium concentration of ethylene fall to zero at the reaction surface, and ethylene dichloride formed as a result of the reaction diffuses into the bulk.

Assuming that the mass transfer coefficient of ethylene is not influenced by the presence of chlorine bubbles, and the film thickness and surface area of ethylene and chlorine at nearly equal velocities are the same, the authors have derived the following expression for the reaction rate:

$$R = \frac{1}{2}k'_A \left(\frac{1}{H_A} + \frac{1}{H_B}\right)$$

where R is the reaction rate (g. mole/cc./hr); H, the Henry's law

constant (atm. cc./g. mole); k', mass transfer coefficient; and the subscripts A and B denote ethylene and chlorine respectively. The general form of the equation for use in cases where the diffusion coefficients are not equal is

$$R = \frac{1}{2}k'_{A}\left(\frac{1}{H_{A}} + \frac{D_{B}}{D_{A}} \cdot \frac{1}{H_{B}}\right)$$

where D is diffusion coefficient. It is enough, if the mass transfer coefficient of ethylene and the Henry's law constants of ethylene and chlorine are determined to find out the reaction rate; and both of them are easily determinable.

According to the proposed model, it is the absorption stage which offers any resistance and the chemical reaction stage is very rapid. This view fits in well with the fact that temperature has very little effect on the rate of reaction.

The rate equation based on this film model predicts values for the reaction rate which are within 1 per cent of experimentally observed data.

Improved equation for latent heat determination

A new equation for estimating the latent heat of vapourization of liquids has been reported by G. Narsimhan of the Indian Institute of Technology, Kanpur [*Chem. Engng*, **73** (No. 12) (1966), 157]. The equation is

$$\lambda_v = \frac{1.987T_c(\ln P_c)(1-T_r)}{(1.963-2.46T_{rb})}$$

where λ_{ν} is the latent heat of vapourization and subscripts c, rand b denote initial state, reduced state and normal boiling point. A special feature of the new equation is that one has to measure only T_c , P_c and T_b . Developed from the Clapeyron equation, this generalized equation can be applied on the entire liquid range, and gives more accurate results than the equation currently used. The new equation predicts the latent heats of vapourization of such liquids as water, ethylene, ethyl bromide and hydrogen dioxide with a maximum error of 2 per cent, whereas with the other equations, the error involved is between 3 and 17 per cent.

Progress Reports

Central Building Research Institute, Roorkee

The annual technical report of the Institute for 1965 presents an account of research and developmental activities of the various divisions during the year. As a substitute for foam concrete, cellular concrete suitable for walling up to three storeys has been developed from fly ash, lime and small amount of aluminium powder (as gassing agent) and its technology has been worked out. Kinetic studies on thermal decomposition of calcium hydroxide have shown that the activation energy decreases with decrease in the size of calcium hydroxide crystals. During studies on the hydration of magnesian and dolomitic limes, the thermogravimetric method, in comparison to the time-consuming conventional methods, has been found to be satisfactory for the estimation of unhydrated MgO. It was observed that some of the non-bridging oxygen ions in the tetrahedral structure of synthetic glasses convert themselves into bridging oxygen ions, to maintain the electroneutrality, with increase compactness of the in the structure.

Studies on the uplift resistance of short-bored piles in loose sandy soil stream have shown that a pull applied at the bottom provides more resistance than the pull applied at the top. From field tests it has been concluded that precast beams can be used instead of the *in situ* casting of grade beams in black cotton soils.

With the help of a computorized technique developed it has been made possible to predict the indoor climate to an accuracy of 7 per cent. Simplified thermal constant-fabric weight graphs have been prepared which enable easy and rapid determination of periodic heat flow characteristics of different elements. Studies are in progress on the development of a mathematical theory for periodic heat flow through floors raised on ground. A new numerical method of solving trigonometric integrals has been developed. It has been observed that a considerable amount of heat (14 per cent of total heat loss on the enclosure

during day time) is through the floor. From studies on the relative efficiencies of shell, sawtooth and folded plate northlight roofs for factories, it has been observed that the bay width and northlight openings remaining the same, the Z-folded plate gives maximum illumination on the working plane. The cylindrical shell provides the minimum illumination, while the sawtooth gives a value in between. With a view to ascertaining the indoor air velocity diffusion in relation to the outdoor prevalent wind velocity, studies were conducted on various building models in a slow-speed wind tunnel and data were obtained. Measurements of sky luminance distribution and solar illumination on horizontal surfaces have been made for providing data for the design of daylight through sidelit windows. Investigations are in progress to establish a relationship between the strength of concrete and the ultrasonic pulse velocity and to correlate the pulse shapes to the various types of defects in concrete.

Studies on the residential densities and landuse relationships have led to the formulation of convenient guidelines to the planners.

The processes leased out to industry during the year include: (1) expansion joint filler from coconut pith and cashewnut shell liquid; (2) know-how for the manufacture of foamed concrete; and (3) new formulations of cement paints.

New Periodical Thin Films

This new quarterly journal to be published by Gordon & Breach Science Publishers, New York, will start appearing from spring 1967. The journal will provide a much needed medium for pure and applied scientists of diverse backgrounds who share a common interest in the science of thin films. It will emphasize the quantitative aspects of thin films by accepting both theoretical and papers primarily experimental from physical scientists. The subjects to be covered will include transport properties, superconductivity, magnetic properties, optical properties, film structure and growth and the application of thin films to studies of the defect solid state. The papers

are to be published in English or, in some cases, in the author's language accompanied by an English abstract. The journal will contain, besides original research papers, letters to the editor, invited review papers and outstanding conference proceedings. Further details may be had from Gordon & Breach Science Publishers Inc., 150 Fifth Avenue, New York City 1004.

Prof. R. B. Arora

Prof. Ram Behari Arora, M.D. (Medicine), M.D. (Pharmacology) FAMS, until recently Professor of Pharmacology, All-India Institute of Medical Sciences, New Delhi, has been appointed Director, Indian Institute of Experimental Medicine, Calcutta.

Prof. R. B. Arora (b. 31 March 1917 at Hardwar) after taking the medical degrees from the Lucknow University was appointed Assistant Professor of Pharmacology, B.R. Medical College, Lahore, in 1946. He joined Lady Hardinge Medical College, Delhi, as Professor and Head of the Department of Physiology and Biochemistry in 1948. Later, he took over as Professor and Head of the Department of Pharmacology, S.M.S. Medical College, Jaipur. In 1951, he proceeded to Harvard University, Boston, USA, as a Rockefeller Fellow for specialized training in pharmacology. On his return from Harvard in 1953, he reorganized the Department of Pharmacology at Jaipur with a substantial Rockefeller Foundation grant. In 1957, Prof. Arora was appointed Professor of Pharmacology at the All-India Institute of Medical Sciences. In 1960, he proceeded to USA with a research and teaching assignment as TCM Fellow. At the All-India Institute of Medical Sciences, he built up a new Department of Pharmacology and Toxicology, making it an outstanding school for training in this field in a few years' time. He has also been interested in research in breeding and maintenance of laboratory animals as Professor-in-charge of these sections at Jaipur and Delhi.

Prof. Arora's main interest is in aetiology, prevention and therapy of coronary thrombosis, atherosclerosis and cardiac arrhythmias. He is also interested in biological standardization of drugs. He has to his credit 139 research publications, including 10 monographs.

Prof. Arora is the recipient of a number of national and international awards. He was awarded a medal and a certificate at the Second International Pharmacological Congress held at Praha, Czechoslovakia, in August 1963. He was the recipient of the Shanti Swarup Bhatnagar Memorial Award for the year 1961 for his contributions to 'Biochemical pharmacology of myocardial infarction'. In 1965, he received the Hamdard National Foundation Award for his work on indigenous plant drugs. In the same year he was awarded the Basanti Devi Amirchand Senior Award, Indian Council of Medical Research (ICMR), for his work on 'New reflections in mechanism and therapy of cardiac arrhythmias'.

Prof. Arora is a member of the Scientific Advisory Board and Pharmacology & Indigenous Drugs Advisory Committees of ICMR; Pharmacy Council of India; Drug Technical Advisory Board, Government of India, Ministry of Health; Pharmaceutical & Drugs Research Committee, CSIR; Committee for the Purpose of Controlling & Supervising Experiments on Animals, New York Academy of Sciences; and Founder Fellow of Indian Academy of Sciences. He is a member of the Indian Medical Association, Indian Pharmaceutical Association, Asof Physiologists & sociation Pharmacologists of India, Indian Cardiology Society, and Indian Association of Medical Education.

Dr Lal C. Verman

Dr Lal C. Verman, the distinguished founder and Director-General of Indian Standards Institution (ISI), retired from office on 2 September 1966 after 19 years of signal service to standards and standardization in the country. After obtaining the Ph.D. degree in Electrical Engineering from the University of Cornell, Dr Verman returned to India in 1931 to join the Department of Electrical Engineering, Indian Institute of Science, Bangalore. In 1934, he was appointed research physicist at the Shellac Research Bureau,

London, set up by the Indian Lac Cess' Committee. Two years later, he joined the Industrial Research Bureau, Calcutta, as a Research Officer. Subsequently, he was in-charge of the physical section of the CSIR laboratories set up in New Delhi at the end of the Second World War. He became Director, ISI, when it was established in 1947. Under his leadership, ISI has expanded into the present huge complex with about 1600 committees, subcommittees and panels. Over 3500 standards have been finalized since ISI started functioning. Dr Verman has also played a prominent role in the field of international standardization. He has been Vice-Chairman of ISO for two consecutive terms and Chairman of its Planning Committee. In 1964, Dr Verman received the Leo B. Moore Medal of the Standards Engineers Society of America.

Dr A. N. Ghosh, formerly Deputy Director-General, ISI, has succeeded Dr Verman as its Director-General.

Announcements

Symposium on Indian • A Ocean, jointly sponsored by the Indian National Committee on Oceanic Research and the National Institute of Sciences of India, will be held at the National Institute of Sciences of India, New Delhi, during 2-4 March 1967. The object of the symposium is to discuss the scientific results of the International Indian Ocean Expedition, 1960-65. There will be group discussions on physical and chemical oceanography, geology and geophysics, biology including fisheries and marine meteorology. Those who wish to contribute papers for the symposium are requested to communicate their names and titles of papers to the convener of the symposium, Dr N. K. Panikkar, Director, National Institute of Oceanography, CSIR, Rafi Marg, New Delhi 1. Abstracts of papers should reach convener by 31 January 1967.

• The Fifth Anniversary Matscience (Institute of Mathematical Sciences) Symposium will be held in Madras for two weeks commencing from 3 January 1967. There will be two sections, one in 'Theoretical physics' and the other in 'Pure mathematics'. Enquiries regarding the symposium should be addressed to the Director, Institute of Mathematical Sciences, Madras 4.

 An International Symposium on Modern Optics, organized by the Polytechnic Institute of Brooklyn, will be held in New York during 22-24 March 1967. It will provide a review of the present status of modern optics as well as a forum for discussion on the latest advances of interest to engineers and physicists. Areas to be covered include holography, spatial filtering, information processing, electrodynamics and optical instruments. The proceedings of the symposium will be published by the Polytechnic Press at a pre-publication price of \$ 11.00. Intending participants should send their papers to the Symposium Committee, Polytechnic Institute of Brooklyn, 333 Jay Street, Brooklyn, NY 11201, USA, before 15 January 1967.

 An International Symposium on Solution Properties of Natural Polymers, sponsored by the Chemical Society, London, will be held in the Department of Chemistry, University of Edinburg, during 25-27 July 1967. The whole field of natural polymers will be covered at the symposium. The subjects for discussion include proteins, nucleic acids, polysac-charides and rubber and the new developments in the techniques to study the behaviours of these materials in solution. Intending participants should communicate with Dr C. T. Greenwood, Department of Chemistry, The University, West Mains Road, Edinburg 9. Scotland, not later than 31 December 1966.

• An International Symposium on Corrins, jointly sponsored by the Chemical Society, London, and the International Union of Pure & Applied Chemistry, will be held at the University of Nottingham during 17-19 July 1967. The symposium will cover the synthesis, structure and properties of corrins, including vitamin B_{12} . Intending participants should write to the General Secretary, the Chemical Society, Burlington House, London, W1. Abstracts of papers to be presented should reach Prof. A. W. Johnson, Department of Chemistry, University of Nottingham, England, by 31 December 1966.

 An International Symposium on Conformation of Biopolymers, sponsored by the International Union of Pure & Applied Biophysics, will be held at the University of Madras during 18-21 January 1967. The symposium will deal with the study of the structure of constituents of living tissues at the molecular level, with special reference to the conformational aspects of biological large molecules like proteins, nucleic acids and polysaccharides. Among the foreign scientists expected to attend the symposium are Prof. Linus Pauling and Prof. D. C. Hodgkin. Enquiries regarding the symposium should be addressed to the Secretary of the symposium, Dr C. Ramakrishnan, Centre for Advanced Study in Biophysics, University of Madras, Madras 25.

 An International Symposium on Plant Pathology, the first in India, will be held at the Indian Agricultural Research Institute, New Delhi, from 27 December 1966 to 1 January 1967. There will be 15 sessions in all, including one at Agra. Enquiries regarding the symposium should be addressed to Dr S. P. Raychaudhuri, Division of Mycology, Indian Agricultural Research Institute, New Delhi, Chairman of the Organizing Committee, or Dr M. M. Payak or Dr B. L. Renfro, of the same Institute, Joint Secretaries of the symposium.

• The Palaeobotanical Society will hold its nineteenth scientific meeting at Birbal Sahni Institute of Palaeobotany, Lucknow, during 21-23 January 1967. The programme includes lectures, reading of papers and a ' conversazione '.

FIRST GET-TOGETHER OF RESEARCH AND INDUSTRY PUBLICATIONS

The Council of Scientific & Industrial Research (CSIR) organized a two-day First Get-Together of Research and Industry in New Delhi during 20-21 December 1965.

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