Journal of Scientific & Industrial Research

154

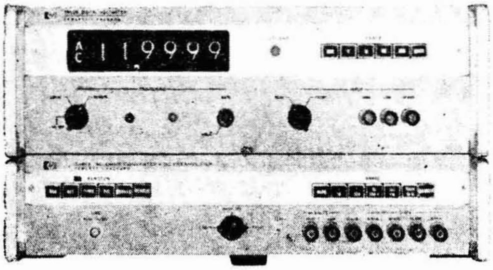
J. scient. ind. Res. Vol. 27 No. 7 Pp. 255-292
July 1968
Published by the Council of Scientific & Industrial Research, New Delhi

Sole Distributors Outside India: Pergamon Press
Oxford London Paris Frankfurt New York

HEWLETT hp PACKARD

PERFECT MATES

New Multiple Function Package Combines Accurate DC



With Ohms AC Volts, Micro-DC Volts

The hp-3460B Digital Voltmeter and hp 3461A ac/ohms Converter-dc Preamplifier combine to make a multiple function DVM with high resolution, high accuracy, and high sensitivity. The package has a 20 per cent over-ranging capability, and an accuracy of 0.005 per cent of dc reading 0.084 per cent of midrange ac reading and 0.012 of ohms reading.

You can make low level dc voltage measurements with 1 μv sensitivity, wide-range ac voltage measurements from 80 Hz to 100 KHz with 10 μv sensitivity and accurate resistance measurements from 1 K ohm to 12 M ohm with 10 milliohm sensitivity on the lowest range.

OPTIONAL COMBINATIONS—To allow minimum investment with flexibility for meeting future requirements, the 3461A can be purchased to include a single function or a combination of functions. Functions not originally purchased can be ordered and easily installed.

SYSTEM USE—High common mode rejection (160 dB at dc and 110 dB at 60 Hz) guarded inputs and speed of reading (2.5 readings/sec for ac and 15 readings/sec on dc) make the combination ideal for use in digital data acquisition systems. Range, function, trigger and integration period are fully programmable for automated measurements. BCD output (1-2-4-8) containing 6 digits of data, polarity, decimal location and overload information.

For details please write to:

SOLE DISTRIBUTORS

THE SCIENTIFIC INSTRUMENT COMPANY LIMITED

ALLAHABAD BOMBAY CALCUTTA MADRAS NEW DELHI

Head Office: 6 Tej Bahadur Sapru Road, Allahabad

SICO 1911–1968

EDITORIAL BOARD

Dr Atma Ram, Director-General, Scientific & Industrial Research (*ex-officio* Chairman), New Delhi

Prof. J. J. Chinoy, Gujarat University, Ahmedabad

Dr S. Deb, Jadavpur University, Calcutta

Dr Hari Narain, National Geophysical Research Institute, Hyderabad

Prof. N. R. Kuloor, Indian Institute of Science, Bangalore

Dr B. R. Nijhawan, National Metallurgical Laboratory, Jamshedpur

Prof. S. R. Palit, Indian Association for the Cultivation of Science, Calcutta

Dr H. A. B. Parpia, Central Food Technological Research Institute, Mysore

Dr A. R. Verma, National Physical Laboratory, New Delhi

Shri A. Krishnamurthi, Chief Editor & *ex-officio* Secretary

EDITORIAL STAFF

Chief Editor: A. Krishnamurthi

Editors: R. N. Sharma & S. S. Saksena

Assistant Editors: D. S. Sastry, K. Satyanarayana, K. S. Rangarajan & S. K. Nag

Technical Assistants: A. K. Sen, S. Arunachalam, R. K. Gupta & T. Prem Kumar

Production Officer: S. B. Deshaprabhu

The Journal of Scientific & Industrial Research is issued monthly.

The Council of Scientific & Industrial Research assumes no responsibility for the statements and opinions advanced by contributors. The Editorial Board in its work of examining papers received for publication is assisted, in an honorary capacity, by a large number of distinguished scientists working in various parts of India.

Communications regarding contributions for publication in the Journal, books for review, subscriptions and advertisements should be addressed to the Editor, Journal of Scientific & Industrial Research, Publications & Information Directorate, Hillside Road, New Delhi 12.

Annual Subscription

A: For Libraries, Government Departments and Industry Rs 30.00 (inland); £ 3.10.0 or $ 10.00 (foreign)

B: For individuals Rs 22.50 (inland); £ 2.5.0 or $ 6.50 (foreign)

Single Copy

Rs 4.00 (inland); 6*s*. or $ 1.50 (foreign)

Payments in respect of subscriptions and advertisements may be sent by cheque, bank draft, money order or postal order marked payable to Publications & Information Directorate, Hillside Road, New Delhi 12.

© 1968 THE COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH, NEW DELHI

Sole Distributors Outside India
PERGAMON PRESS
Oxford London Paris Frankfurt New York

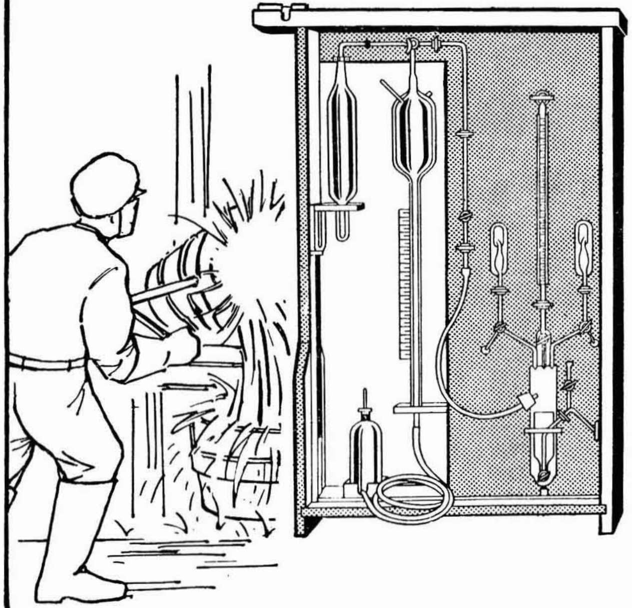
Journal of Scientific & Industrial Research

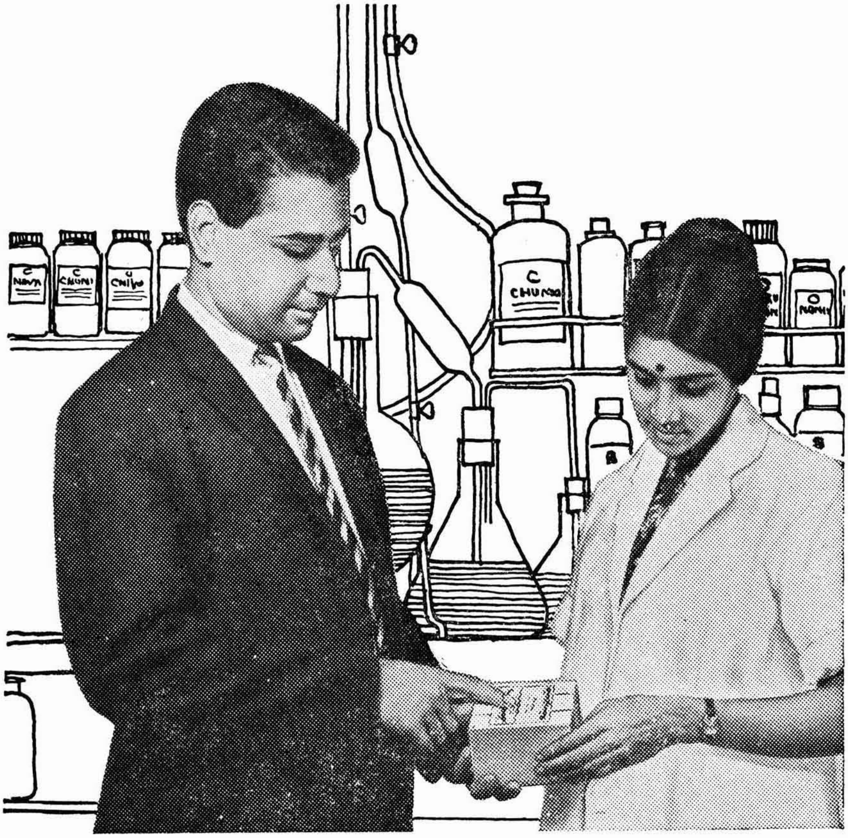
VOLUME 27 • NUMBER 7 JULY 1968

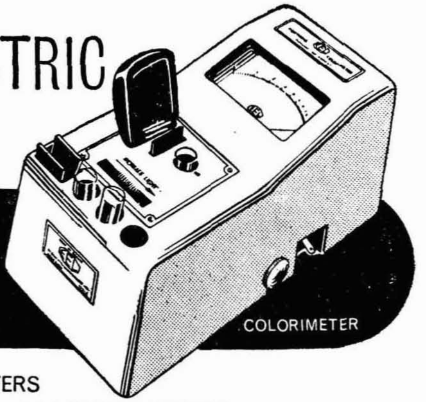
CONTENTS

For Index to Advertisers, see page A19

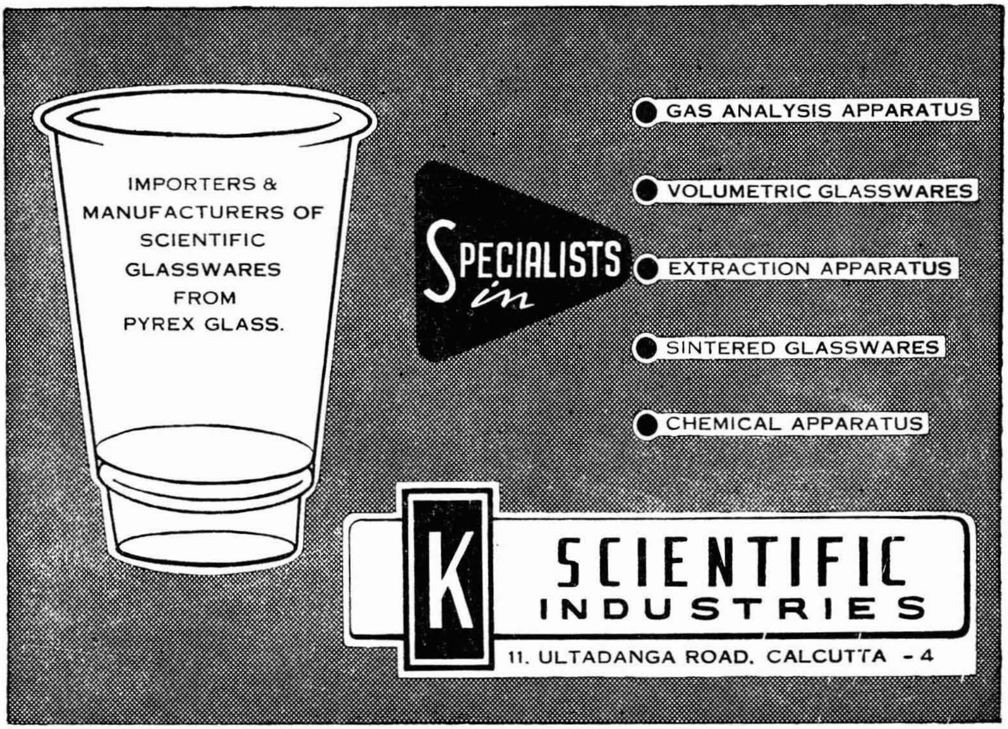
ห้องสมุด กรมวิทยาศาสตร์

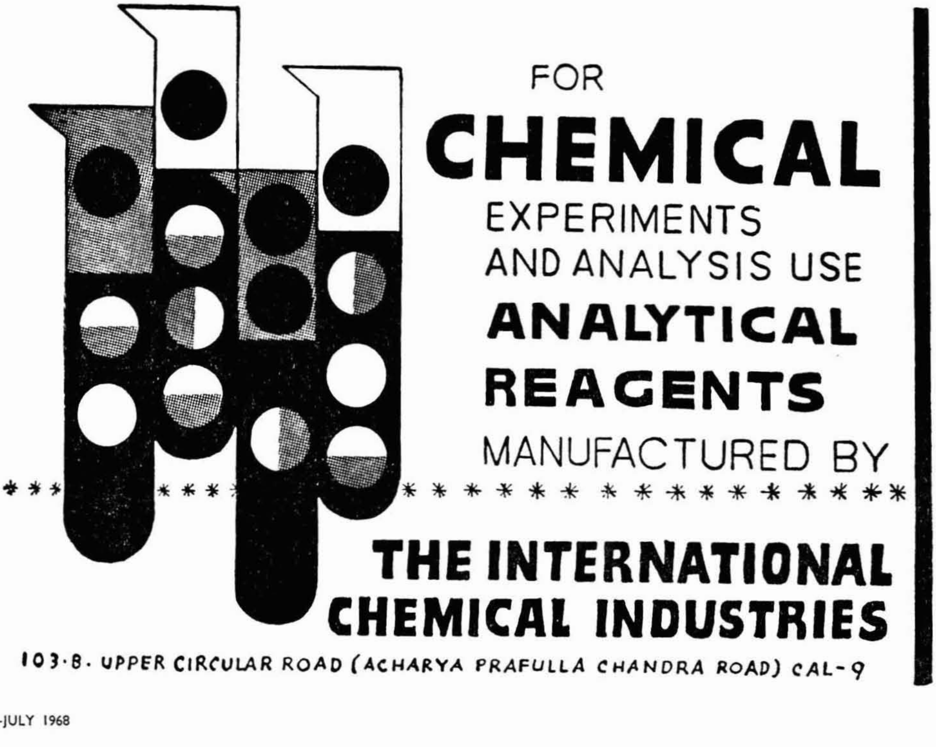



C
NaVA
C
CHUNI
C
CNIlya
C
CHUNSO
O
NOMY



COLORIMETER





THE 'ROTO SUPER' CENTRIFUGE

An efficient HIGH-SPEED (6000 r.p.m.) LABORATORY CENTRIFUGE with all the features of Modern Centrifuge Engineering.

With brake and regulating ring transformer, electric speedometer, automatic timer with safety device to avoid any sudden start, with control lamp, and complete with the following accessories:

- **Swing Head for 4×100 ml. complete with shields of V2A steel and glass tubes**
- **Reducing Insertion of 50 ml. complete with glass tubes (fitting the swing head)**
- **Multi-Carrier of 2×25 ml. complete with glass tubes (fitting the swing head)**
- **Multi-Carrier of 4×15 ml. complete with glass tubes (fitting the swing head)**

Literature and prices on request

Various other models also available

B. PATEL & COMPANY

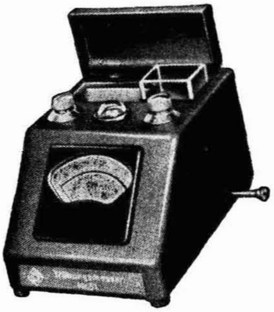
DIRECT IMPORTERS & STOCKISTS OF SURGICAL & SCIENTIFIC GOODS

27/29 POPATWADI, KALBADEVI ROAD, BOMBAY 2

Phones: 314689 & 315702 Grams : GLASALSORT

An invitation

Dr Brune Lange PHOTOELECTRIC NEPHETOMETER



For your needs in

Scientific and Laboratory Instruments, Apparatus and Appliances

*** PHOTOELECTRIC COLORIMETERS, RESEARCH MICROSCOPES, pH METERS, ETC. * GLASSWARE * SILICA/PORCELAINWARE * FILTER PAPER * CHEMICALS, ETC.**

Quality products of repute—both Imported and Indigenous

Available ex-stock Bombay

Please write for price list

SCIENTIFIC SALES SYNDICATE

Palkhiwala Building, 24 First Dhobi Talao Lane
BOMBAY 2

Telephone: 29160 Telegram: CENTROFIX

GRAM : : 'ASHACOM' PHONE : 22855

SUPERIOR LAMP BLOWN PYREX GLASS APPARATUS; ASSEMBLIES ACCESSORIES OF ALL TYPES

Manufactured by

SCIENTIFIC EQUIPMENT MFG. CO.

An associate of

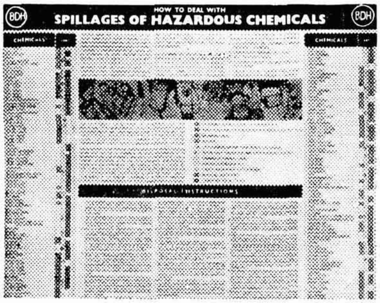
ASHA SCIENTIFIC CO.

DIRECT IMPORTERS & MANUFACTURERS' REPRESENTATIVES,

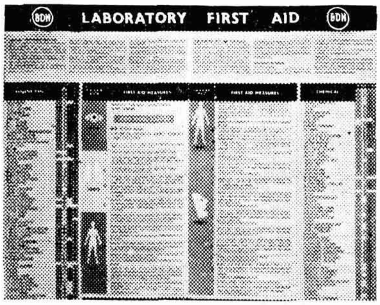
503, GIRGAUM ROAD, BOMBAY 2.

Interchangeable Laboratory Glassware 'Our Speciality'

WE SUPPLY COMPLICATED RESEARCH APPARATUS

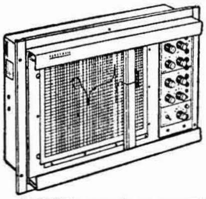


HOW TO DEAL WITH
SPILLAGES OF HAZARDOUS CHEMICALS

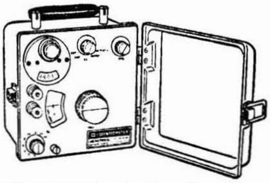


LABORATORY FIRST AID

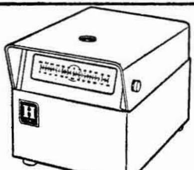
Improve your testing facilities with HONEYWELL instruments



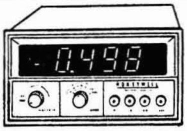
The XY and XYY' recorders provide sensitivities from 500 μV to 100 μV/inch, chart sizes of 8 $^1/_2$ x 11 and 11 x 17 inches, potentiometric input impedance, Zener reference and built-in time base. The series 320 is a low cost portable recorder having most of these specifications.



A wide range of potentiometers for calibrating instruments, temperature measurements and for standards laboratories are available with spans ranging from 211 μV to 11.11 V. The illustrated model 2704 is compact and ideally suited for calibrating instruments.



The spotlight and pointer, taut-suspension, moving coil galvanometers provide sensitivities from 3.5 μA to 0.0006 μA/mm with input resistances ranging from 10 to 4900 ohms. Also available are photoelectric galvanometers having upto 10 $\mu\mu$A/mm sensitivity and a sensitive electronic null detector.



The digital multimeters read combinations of DC and AC voltages, resistance, capacitance, frequency and period, providing 4 to 6 digits display, upto 1 μV resolution and common mode rejection from 144 to 60 db at 50 cps. The illustrated 620 series measures DC voltage upto 750 V. Accessory modules with plug-in cards for AC voltage and resistance measurements are optionally available.

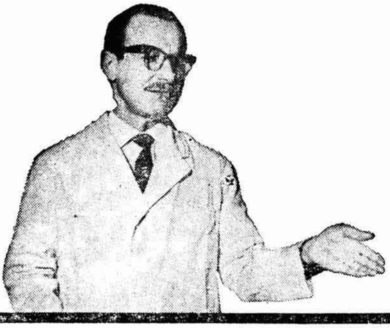
Also available are Wheatstone, Kelvin and Mueller bridges, conductance bridges, monitor oscilloscopes, ultra-violet direct-writing oscillographs, DC amplifiers, integrators, data loggers and tape instrumentation recorders.

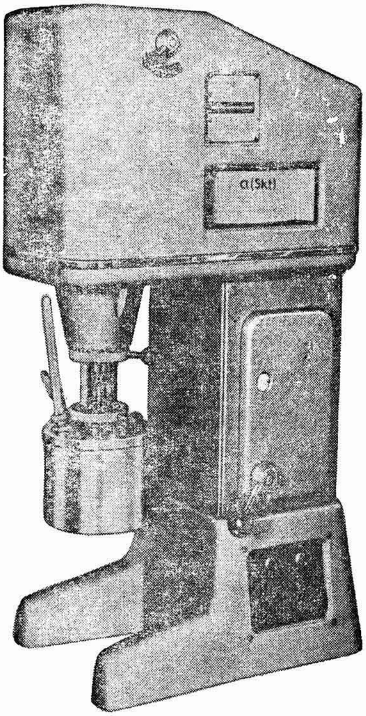
Sold and serviced in India exclusively by

Honeywell ★ **BLUE STAR**

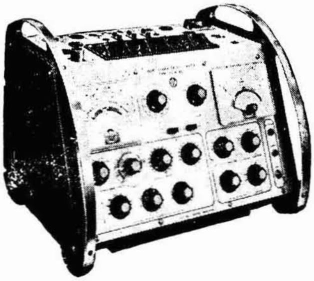
Get complete details from BLUE STAR offices at:
Band Box House, Prabhadevi, Bombay 25 • 7 Hare Street, Calcutta 1 • Connaught House, Connaught Circus, New Delhi 1 • 23/24 Second Line Beach, Madras 1 • 14/40 Civil Lines, Kanpur 7-1-21 Begumpet, Hyderabad 16 • 1B Kaiser Bungalow, Dindli Road, Jamshedpur

PS/BS/60/68



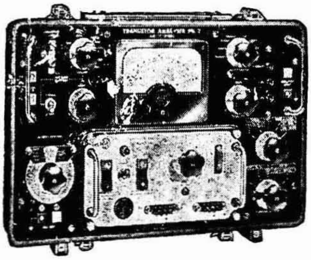


α(Skt)



Avo valve characteristic meter VCM163
The Type V.C.M. 163 is the most comprehensive Valve Characteristic Meter ever to be developed by Avo. Provision is made for testing the recently introduced Nuvistor and Compactron types and in fact, valves with any number of pin connections up to 13 can now be tested.

Transistor and Diode Tester TT 537
This new transistor and Diode Tester provides in one instrument, facilities for both transistor and diode testing. Provision is made for the rapid and accurate measurement of hfe and leakage current for both p.n.p. and n.p.n. low and medium power germanium or silicon transistors. Both the forward and reverse characteristics of the diodes can be measured.



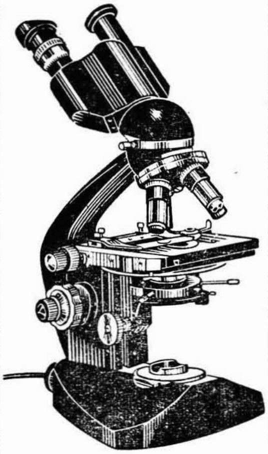
Transistor analyser MK 2
This is a portable-direct-reading instrument, simple to operate and moderately priced, yet capable of giving accurate transistor measurements in the grounded emitter configuration.

Avo universal measuring bridge B150
A new, battery operated, general purpose measuring bridge, featuring a unique digital in-line display.

SISTA'S-ML-1

METRONEX **VARIMEX** **Kleertone**

THE BEST THREE



1. METRONEX MICROSCOPES AND LABORATORY INSTRUMENTS

a. A wide range of Biological, Research, Monocular and Binocular Microscopes.

b. Industrial Microscopes, Projection Microscope (Lanameter), Workshop microscope etc.

Models — MLP — Portable, Monocular Microscopes with spring protected oil immersion.

ML5 — MB2 — MB30 — Binocular Research Microscopes with and without.

Built in illumination — Spring Protected 40 x — 100 x objectives.

b: Analytical Balances. Automatic, Semi automatic, Semi-micro analytical balances — Single Pan and Double Pans.

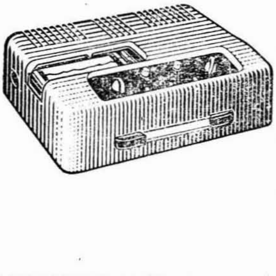
2. VARIMEX ELECTROMEDICAL EQUIPMENTS:

a. Audiometer — Portable and Clinical. Half — automatic Recording nine and eleven kinds of tests. Models: AUG: 64 and AK: 64.

b. Low Frequency Electro therapy Diadynamic apparatus: Models DD4, DD5 and SX1 for physiotherapic treatment.

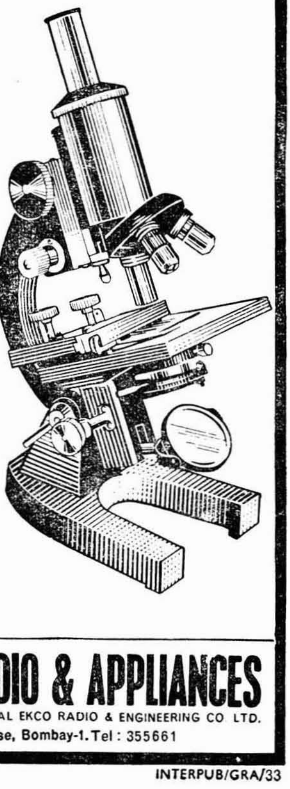
c. Electro Cardiograph — Portable, hot stylus, direct recording systems, half transistorized

d. Medical PH meter — Battery mains operated accuracy — 0.005 PH. Blood PH metry and Potentiometric titration possible.



3. KLEERTONE LABORATORY AND INDUSTRIAL INSTRUMENTS.

Microscope, Stirrer, Centrifuges, Motors, Electronic equipment, etc.

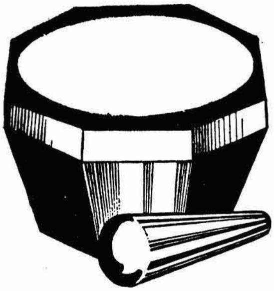


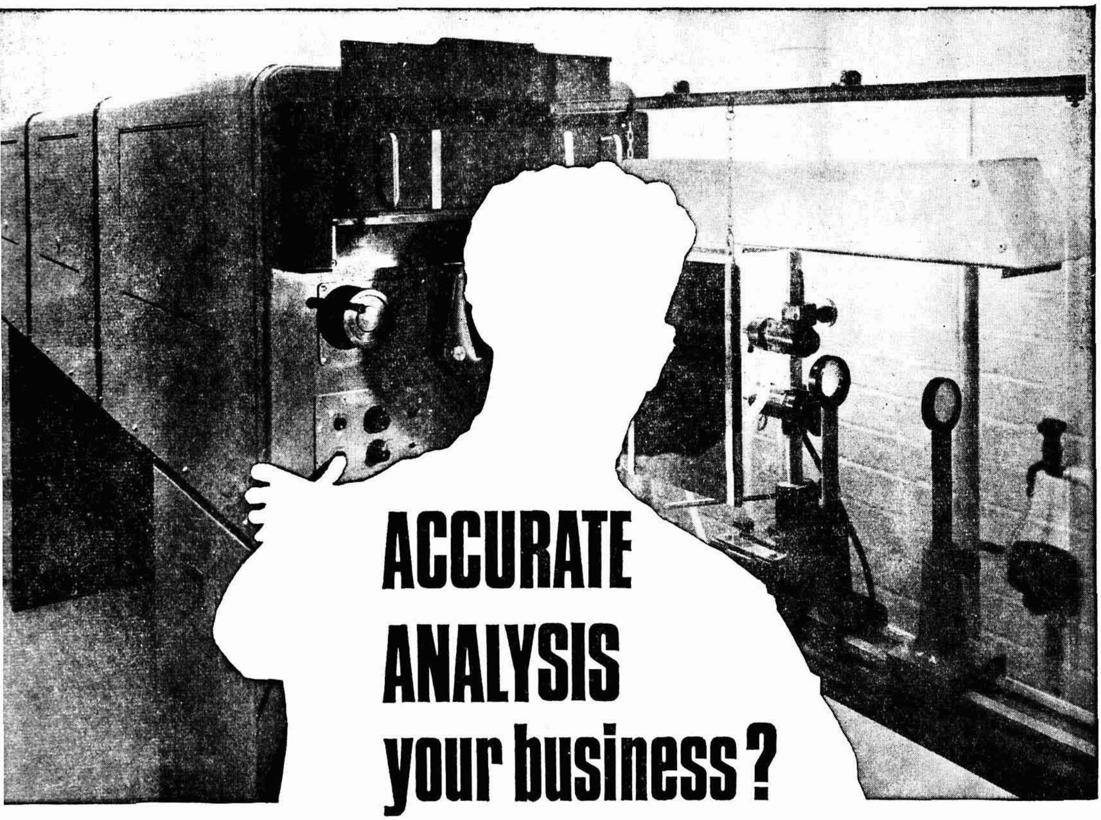
GRA GENERAL RADIO & APPLIANCES

A DIVISION OF THE NATIONAL EKCO RADIO & ENGINEERING CO LTD.

8, Unity House, Opera House, Bombay-1. Tel: 355661

INTERPUB/GRA/33





For highest accuracy from your analytical technique you should always rely on JMC spectrographic materials.

Ask for our catalogue and price lists today!

Spectrographically Standardised Substances

Metals and compounds of the highest purity, representing 70 elements, make up the JMC range of spectrographically standardised substances. These substances are employed as reference standards in qualitative spectrography and in making standard mixtures containing known amounts of certain elements for quantitative work. Electrode materials are included in the range. Individual supplies of each substance are accompanied by an analytical report giving the level, in parts per million, of each impurity detected in the batch.

Spectrographic Carbon and Graphite

JMC carbon and graphite products are available in various grades of purity to meet all the exacting needs of the spectrographer. Uniform high quality, both chemically and in physical properties, is ensured for these materials by stringent tests that are applied to all forms.

Spectrographic Flux

In the spectrographic analysis of ores, refractories and slags, speed and increased accuracy are gained by fusing the sample with a flux that breaks it down into a standard form. JMC spectrographic flux, based on lithium borate, has been developed specifically for this purpose.

JMC Spectrographically Standardised Substances

Available through:

The Andhra Scientific Co. Ltd.,
4, Blackers Road, Mount Road,
MADRAS-2.

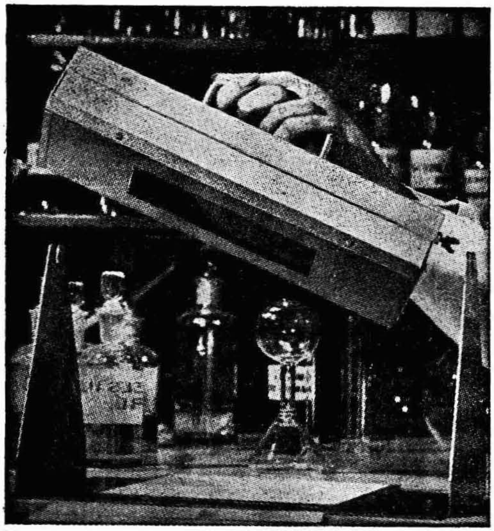
Arora-Matthey Limited
166, Netaji Subhas Chandra Bose Road,
Tollygunge, CALCUTTA-40

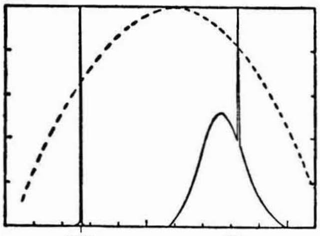
Associated Instrument Manufacturers (India)
Private Limited,
Sunlight Insurance Buildings,
26-27 Asaf Ali Road, NEW DELHI

Raj-Der-Kar & Co.,
Sadhana Rayon House,
Dr. D. Naoroji Road,
BOMBAY-1

The Scientific Instrument Company Ld.,
6, Tej Bahadur Sapru Road,
ALLAHABAD-1

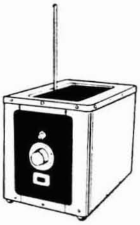
JOHNSON MATTHEY CHEMICALS LIMITED, HATTON GARDEN, LONDON, ENGLAND

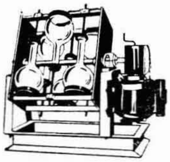




254 mμ
366 mμ

INDEX TO ADVERTISERS





A Note on Unemployment of Engineers in India*

MALCOLM S. ADISESHIAH

Deputy Director-General, United Nations Educational, Scientific & Cultural Organization, Paris

Statistics

ENGINEERING unemployment in India has topicality as a subject and urgencies as a socio-economic problem. As early as 1965, employment exchanges were sending up danger signals resulting from sharp increases in the number of engineers on their live registers. In the 1967 university convocations, there were repeated demonstrations by engineering graduates who refused to attend the ceremonies or who staged walkouts to emphasize their demand for jobs and not speeches. United Nations meetings concerned with development assistance to India have discussed the issue, albeit discursively. The twenty-fifth session of the Indian Labour Conference, held a few weeks ago, in reviewing national employment policy, also discussed this question. The Lok Sabha, at its 2 May session, spent half of its question period on the problem, thereby "reflecting the deep concern of members over the growing trend of unemployment among the educated classes". The House was assured that "when the present studies by the Planning Commission in consultation with the employing ministries are completed, a plan providing new and increased avenues of engineering employment would be chalked out". Apart from the human aspects, as the unit cost of engineering education is the third highest of that of any educational speciality, engineering unemployment represents considerable waste of scarce resources and priority investment.

The term 'engineers' in this note is used to cover university graduates in engineering and diploma engineers or technicians graduating from polytechnics. The statistical picture with regard to unemployment among engineers in India is not precise. Other figures in this note are likewise marked by similar imprecision. The governmental authorities are now in the process of establishing an exact statistical map of the problem of engineering unemployment in the country. The Ministry of Education and the Department of Economic Affairs of the Ministry of Finance estimate that the number of unemployed university engineers and diploma technicians was around 30,000 in June 1967. Further computations based on interpretation of employment exchange records and live register figures for the period 1962-67 place the figure at around 40,000 as in December 1967, consisting approximately of 6,500 graduate engineers and 33,500 diploma holders.

In the next few weeks, some 14,800 engineering graduates and 24,500 diploma technicians will be graduated from the educational institutions and a percentage of this output would add to the estimate of engineering unemployment referred to above. Two of the fourteen states — Mysore and Kerala — have announced their current estimates of unemployed engineers at 3,000 each.

Studies by the Institute of Applied Manpower Research show that there is no unemployment among the highest level engineering graduates coming out of the Indian Institutes of Technology.

Causes

Built-in Long-Term Causes

Unemployment and educated unemployment — Unemployment among engineers is part of the wider problem of unemployment and educated unemployment in India today. According to the draft Fourth Five Year Plan, the total labour force in India in 1966 stood at around 205 millions. The 1961 census indicates that this included about 6·2 millions having matriculation and higher education qualifications. This then is the highly educated component of the labour force which is commonly referred to in discussions of educated employment and intellectual unemployment. At the same time, the total unemployed was estimated at about 9-10 millions, of which the educated unemployed, according to various studies, may be placed at between 870,000 and 930,000*. The increase in unemployment from 7 millions in 1961 to 9-10 millions in 1966 is attributed by the draft Fourth Plan to population growth, urban migration and educational expansion. The 30,000-40,000 unemployed engineers are thus part of the larger problem of intellectual unemployment in India currently estimated to cover about 900,000 persons. In other words, educated unemployment contributed 14-15 per cent of the educated labour force and the age

---

*Based on communications to the Deputy Director-General addressed by the Special Secretary, Department of Economic Affairs, Ministry of Finance, Government of India; Joint Educational Adviser, Department of Technical Education, Ministry of Education, Government of India; Member in Charge of Industry, Planning Commission, India; Chief of Unesco Mission and Director, Field Operations, India; and Programme Adviser, Ford Foundation, India. The note, however, is the writer's responsibility.

*My wife, who is a sobering influence, questions the validity of this computation of intellectual unemployment in India, from the point of view of applicability of the usual labour, employment and unemployment concepts to the Indian socio-economic scene. She points to the possible errors of what Myrdal's *Asian drama* describes in more technical terms as the errors of 'misplaced aggregation' and 'illegitimate isolation'.

distribution of the educated unemployed shows the highest incidence of around 80 per cent in the age group 15-24.

Education and manpower — There has been so far little relation between the educational system and manpower estimates. As the Education Commission states: " In the present education system there is no direct link between education and employment and no attempt is made even to establish an indirect link by relating the output of the educational system closely with manpower needs or job opportunities."

Despite the forecasts attempted by the Planning Commission and its committees, the situation with regard to engineering education is not much better. The 1964 Estimates Committee of the Lok Sabha commented that it was " unfortunate that engineering personnel plans have been formulated on rough approximations, without taking into account the actual requirements. Government should pay immediate attention to the question of devising a suitable methodology of forecasting engineering manpower requirements, so that a realistic programme can be made."

Dramatic expansion of engineering education — Engineering education in India has expanded at incredible speed. The output of degree-level engineers increased fivefold during the period 1951-66, from 2,198 to 10,282, and the output of diploma-level engineers increased nearly eightfold, from 2,478 to 18,029. From 1960 to 1965 alone, the annual graduation of mechanical engineers increased from 1,311 to 3,136, and that of graduate electrical engineers from 923 to 2,320. Between 1960-61 and 1965-66, the total stocks of graduate engineers have increased from 58,000 to 93,000 and diploma holders from 75,000 to 136,000. On the basis of the present admission capacity, the rapid expansion in intake during the national emergency (1962-64), which will be felt in the next few years, and a 2 per cent attribution rate, by 1973 the stocks will be 219,000 and 316,000 and by 1978, 299,000 and 425,000 respectively. This rapid expansion is an expression of the high priority that India after independence accorded to development of engineers in the face of acute shortages. So successful has the expansion been that whereas in 1964 the Estimates Committee " noted its concern that there would be a sizeable gap between demand and supply position of engineering personnel during the Fourth Plan ", the draft Fourth Plan forecast sufficiency and some surplus and made no provision for increasing the number of engineering graduates.

Parameters — The projection of future demand in India's Five Year Plan was based on two premises: that engineering manpower, composed of degree holders and diploma holders in engineering, would grow at the same rate as the engineering-intensive sectors of the economy, that is, at the annual rate of 10·3 per cent (the overall annual growth target was assumed to be 5 per cent) and that a ratio of 3:1 between diploma holders and degree holders could, and should, be achieved by 1986. On the basis of these parameters, the draft Fourth Plan stated that degree-level education required little expansion from 1966 to 1971. Only 1,300 seats were required to ensure that engineers with certain narrow specialities would be available to meet the demands of new industries and technological development. An increase of 14,700 seats in diploma-level institutions was, however, foreseen to meet the requirements of the Fifth Plan.

In actual fact, the percentage increase of the National Net Product during the period 1961-62 to 1964-65, according to the draft Fourth Plan, was 4·2 per cent and according to the Central Statistical Organization was 4·3 in 1961-62, 2·1 in 1962-63, 5·4 in 1963-64, 7·4 in 1964-65, –4·8 in 1965-66 and 1·7 in 1966-67. Using the present trends and an average growth rate of 5·5 per cent, unemployed engineers may increase in the future to 55,000 by 1968-69, 69,000 by 1969-70 and 112,000 by 1973, declining after that. Another way of expressing this trend is the purely statistical computation that full employment of engineers during the period 1969-73 will require an overall annual growth rate of 8 per cent and a rate of growth of 16 per cent per year of the engineering-intensive sectors of the economy as from 1969.

Distribution of unemployment — There are shortages in the supply of engineers in certain specialities and there are surpluses in others. As the Education Commission Report points out, there are shortages in metallurgy, chemical engineering, fuel technology, production engineering for heavy machinery manufacture, machine tools, electric equipment, metallurgical works, fertilizer, chemical and other manufactured goods. On the other hand, there are surpluses in civil and, mechanical and, to a lesser extent, in electrical engineering, generally in the traditional type of courses offered in the majority of institutions. The draft Fourth Plan urges specialization, on the basis of demand, in refrigeration engineering in place of mechanical, and highway engineering in place of civil engineering in polytechnics.

This paradoxical situation of surpluses and shortages is illustrated in Tables 1-3 drawn from the 1966 Report of the Technical Manpower Committee and more recent studies by the Directorate of Scientific and Technical Personnel, CSIR.

TABLE 1 — SHORTAGES IN TOTALS

Engineering manpower	Stock in 1965-66	University output in 1966-70	Additional demand 1966-70
Graduate engineers	93,000	85,500	86,000
Diploma engineers	133,000	132,000	140,000

TABLE 2 — SURPLUSES IN BROAD ENGINEERING FIELDS

Engineering speciality	Stock in 1965-66	University output in 1966-70	Additional demand 1966-70
Graduate civil engineers	36,000	21,000	14,200
Graduate mechanical engineers	26,000	30,000	26,000
Graduate electrical engineers	21,000	22,000	19,000

TABLE 3 — SURPLUSES AND DEFICITS IN ONE FIELD (METALLURGY)

Year	Qualifications	Required	Likely	Surplus (+) or shortage (−)
1970-71	Degree	2 649	4,776	+2,127
	Diploma	2,970	934	−2,036
	Total	5,619	5,710	+91
1975-76	Degree	4,099	8,123	+4,024
	Diploma	4,657	1,716	−2,941
	Total	8,756	9,839	+1,083

Imbalance — There is also a general problem of under-employment which the draft Fourth Plan computes at some 16 millions. University engineers are widely used in technician-level employment, indicating a serious under-utilization of degree engineers. Precise statistical information on this imbalance is not available, but there is clear evidence of its existence. Instead of the normal employment ratio of three technicians to one engineer (3: 1), the Indian ratio of employment of technician to engineer is 1: 1 in the Institute of Applied Manpower Research calculations and a maximum of 1·43: 1 in more generous computations. This imbalance is an indication of the under-utilization of engineers, and a waste in the extra investment in their education. Morale is low and diploma-level engineers resent the fact that employment opportunities are closed to them.

Lack of mobility — Programmes to increase and narrow engineering specializations and expand the number of diploma engineers run up against the lack of inter- and intra-state and inter-industry mobility of engineering personnel and the lag in regional, state and area development planning to accelerate employment opportunities. CSIR studies show that only one diploma engineer out of six moves out of his own state. Not only is inter-state movement very low, so too is movement from one centre to another within the same state. This accounts partly for the curious coexistence of unemployed engineers and vacancies, in the country and even within the same state, in posts for which they are qualified, a fact which is referred to later. In densely populated states like Kerala and West Bengal, development plans and policies are only now being adapted to the increasing employment demands of the areas.

Vacancies — There are a large number of unfilled vacancies in posts for engineers. According to Technical Manpower published by CSIR, in the Geological Survey of India, 20 per cent of the approved staff positions are vacant. According to the Education Commission, in the 83 engineering colleges, of the 4,800 teaching posts, 1,900 are still unfilled. This represents a 40 per cent vacancy. In 221 polytechnics, out of 5,500 teaching posts, 1,700 or 31 per cent are vacant.

Macro-problems — In a vast country like India with a population today of over 520,000,000 every problem has vast quantitative connotations. Even a 0·01 per cent movement involves hundreds of thousands. Gandhiji described this peculiarity as Himalayan. With the present state of our knowledge or lack of knowledge in manpower forecasting and techniques for forecasting of economic development, in a country like India, a very small percentage error takes on Himalayan proportions in its impact.

Short-Term Causes

India-Pakistan war — The war brought about a slow-down in industrial development and together with the earlier Chinese confrontation has diverted resources from industry and development to defence. According to the 1967 Report of the Secretary General on the effects of the possible use of nuclear weapons, document A/68583, with an annual defence budget of around 1·7 billion dollars, India in 1965 occupied the sixth highest place in the magnitude of defence expenditure among 41 state members, following the United States, the USSR, the United Kingdom, the Federal Republic of Germany and France.

Droughts — The two droughts in 1965-66 and 1966-67 led to further decreases in agricultural production and the complete disappearance of any surplus to support industrial development. The percentage decrease in agricultural production was 16·3 and 16·5 for those two years as compared to 1964-65. It has not only decreased savings but has also forced diversion of investment resources from manufacturing to the agricultural sector. The total savings decreased from 9·6 per cent of GDP in 1964-65 to 9·2 per cent and 8·8 per cent in 1965-66 and 1966-67.

Reduction in development investment — Investment in both the public and private sector in large and medium industries, as a result of the above causes, has over the last years been cut back. In 1965-66 it amounted to 823 crores and is estimated at 900 crores in 1966-67 and 880 crores in 1967-68. In the public sector there has been a sharp reduction in investment in manufacturing industries and particularly in the engineering industries.

Non-synchronization between the rates of growth and the rates of educational output — As the Education Commission Report points out, the growth targets for the period 1961-66 of 5 (not 6·6) per cent per annum established by the government were not realized. In fact, during part of the period, as seen earlier, the growth rate has been nil or even a minus quantity. The manufacturing and engineering industries have suffered three or four years of recession. However, the educational enrolments, which include enrolment in the engineering institutions, have not and could not be adjusted annually to coincide with the variations in growth rates and the recessional phases of the economy, but have continued on the assumptions concerning overall growth targets.

To paraphrase the conclusion of one of the studies, under more favourable economic circumstances, India's planners could congratulate themselves for having developed technical education facilities capable not only of closing the once large supply-demand gap by 1966 but also, without further expansion, of producing enough engineers to meet the economic requirements during the Fourth Plan. But a succession of events: two wars, two monsoonless years, devaluation and its immediate after-effects, diversion of highest investment priority and resources to agriculture, the failure to conclude a Fourth Plan, postponement of new projects in the manufacturing sector, the shortfall in hydel power consequent on the droughts, the economic recession, the tight budgetary position and cut-backs in industrial and heavy machinery investment have all conspired to stunt the growth of the industries, normally depending upon engineers. In one sense, the educational plan is succeeding far too well, actually exceeding its targets, while the productive sectors lag behind theirs, resulting in many fewer employment opportunities than anticipated. No sooner does India attain quantitative sufficiency of technical manpower than it is confronted by the problem of surplus engineers.

Remedial Action

Long-Term Action

Long-term action with regard to unemployed engineers must be within the framework of the action relating to the problem of educated unemployment in the country. The Education Commission recommends two actions in this regard.

Job-guarantee — It proposes a scheme under which every graduate would be guaranteed a job. It states: " We might consider whether it would be possible to establish a direct link between education and employment. Under a good arrangement, every graduate should be given, along with his degree or diploma, an offer of appointment as well. This offer need not be binding and it may be left open to the student, with the approval of the government, to accept another offer. Moreover, the period of the offer may also be made brief — one to three years — so as to avoid any undue hardship. But a compulsion on the state to make such an offer would be the surest guarantee that the output of the educational system is closely linked with employment opportunities or manpower needs. It will also improve the motivation of the students, give a purpose to their education and make them feel that the country needs them and is waiting for them. In our opinion, this change could be an important factor in raising standards in higher education and in reducing the problems of discipline to the minimum."

In putting forward this proposal for consideration, the Education Commission points to various counteracting problems in the country which must be taken into account in the formulation of a graduated practical plan. There is also much to be learned from the experience of several countries in both the socialist and non-socialist world which operate such a system. The experience of the United Arab Republic, in which every graduate is guaranteed a job, has been the subject of an important seminar organized recently by its Institute of Planning to evaluate the results of this policy. The conclusions of the seminar indicate further factors which must be taken into account in job-guarantee programmes in a non-socialist economy.

Integration of education with overall development— The other action suggested is to tie in the education system with the entire social and economic planning of a country. The Education Commission sets forth such an action programme in the words: Significant problems of life cannot be solved in isolation. The planning of education is no exception to this general rule and, in our opinion, it may not be possible to find a satisfactory solution to it unless wider issues are solved. For instance, if manpower planning is to be successful in the sense that there would be a trained man available for every job to be done and that an appropriate job would be available for every educated person, it is necessary to prepare an integrated plan of development — a plan which will consist of three parts: family planning, economic development and educational reconstruction. At present, the labour force cohort (i.e. the boys and girls who attain the age of 16 or over and enter the labour force in a given year) suffers from several serious defects or difficulties such as the following:

(i) Its size is too large — about 2 per cent of the total population — owing to the large birth rate.

(ii) Its educational attainments are also very meagre — about 60 per cent of the cohort is illiterate and about 40 per cent would have completed primary schooling and attained permanent literacy. Of the latter 40 per cent, about 25 per cent would have received more than five years of schooling and probably completed the primary school course; about 8 per cent would have completed the secondary school; and only about 1 or 2 per cent might be graduated. The proportion of the educated persons in these cohorts is far too inadequate for the creation of a modern social order. What is worse, the little education that has been given is so predominantly academic that there are no trained persons to man the key posts in certain sectors of industrialization now being developed.

(iii) The rate of economic development, especially in rural areas, is so slow that there are not enough jobs for even half of this cohort.

If this situation is to be improved it is necessary to prepare an integrated plan of development with these objects:

(i) to reduce the birth rate to about half in a planned programme of 10-15 years;

(ii) to bring about a very rapid economic development in such a manner that there would be a job for every young man or woman who enters the labour force; and

(iii) to provide such education to the young boys and girls as will qualify them, by having a specific job to do, to participate effectively in the national development programme.

Such plans are needed at the national, state and even district levels. Their preparation and implementation is the responsibility of the government — Central, State and Local. It is only in the wider perspective of such plans that the problem of educational planning can be successfully solved.

And so too, I would add, the intractable problem of unemployment and intellectual unemployment.

Accelerated development — Accelerated economic growth and the return of the industrial and agro-industrial sector, and particularly the engineering-intensive group, to the planned 10-11 per cent growth rate, will alone meet this problem of surplus of educated and engineering manpower. Present indicators in the agricultural and manufacturing sector seem to forecast beginnings of an upward swing from recent recessionary trends. Such indicators need to be nurtured and strengthened.

These long-term perspectives are sobering. For one, the perspectives should not be too long run, because in the long run we are all dead and there is no problem. For another, there are many constraints and prospects that a plan must meet and employment is only one. As the draft Fourth Plan states " In each sector there are compelling requirements which have to be met, so that the scope for large changes in the plan from the angle of employment is somewhat limited ". It is over a long period of 10-15 years that it is possible so to influence development policies, investment priorities and resources allocations as to meet and resolve the problems of employment and unemployment.

Short-Term Action

Reduced enrolment — The most obvious remedial action that suggests itself is a cut in intake of engineering institutions. The government has decided to reduce planned enrolment for the next academic year in certain engineering institutions to achieve an overall reduction of some 35 per cent over the planned intake for the academic year 1968-69. Some state governments, such as Bihar, Orissa, and Jammu and Kashmir, have announced reductions up to 50 per cent. The overall cut of 35 per cent is not to be applied uniformly in all institutions or in all specializations, since the aim essentially is to prune admissions to weak and inadequate institutions and the traditional fields of engineering, so that the technical competence and employment potential of the qualifying students are improved in the process. The 35 per cent reduction will be achieved by not starting new institutions which had been planned for the next academic year, by severely cutting admissions in recently established institutions where the necessary instructional facilities are inadequate, by reducing admissions in old but weak institutions, and reducing the intake in the generalized areas of civil and mechanical engineering while continuing or expanding, as appropriate, the planned enrolment in the specialized areas where there continue to be shortages.

For the future, it is essential that *ad hoc* uncoordinated reductions, which could in a decade or less produce critical shortages, should be avoided through a carefully considered and rational policy based on studies of future engineering demand, which is a function of such factors as the relationship between economic growth and the demand for engineers, the different levels of economic and technological development, changes in employment practices and staffing norms. These studies should be reinforced and based on local employment market surveys and not on the false assumption that there is a fully mobile national labour force. Agencies such as the Institute of Applied Manpower Research and CSIR are equipped to complete such studies in a year.

Reorientation of curricula — The strengthening and reorientation of the curricula of the engineering institutions begun some years ago will be further extended and speeded during this period of a pause in quantitative expansion. Post-graduate instruction, a growing research programme and closer relations with industry, including adequate specialized industrial training are the major features of this restructuration, together with a programme for the training of teachers in regional colleges. The institutions that are aided by Unesco, like other quality institutions, will also share in this strengthening of their curricula through post-graduate courses, expanded research and industrial counselling and closer ties with industry through practical training.

In fact, these measures could also include the study of the desirability of upgrading some institutions which would also reduce under-graduate capacity, the conversion of some degree into diploma institutions, the closure of sub-standard institutes and sandwiching of degree and diploma courses in some institutions.

Utilization — Reduction in enrolments and curricula changes will begin to adjust the supply-demand relations three years later for diploma and after five years for graduate engineers. Immediate measures must be devised for reducing engineering unemployment. For this, a more imaginative and fuller use of engineers for development purposes is suggested. Currently unemployed engineers can be put to work on pre-planning investigations, documentation for future projects and preliminary survey work. With the new teaching, practical training and research orientation of the engineering institutions, graduating engineers could be assisted along fresh employment avenues, in starting small manufacturing units of their own or establishing small-scale industries for or in rural areas, assisted by loan facilities.

Considerable preparatory work by engineers — degree and diploma holders in equal numbers — in the way of surveys, studies, designs and costing for the current Fourth and the future Fifth Plan is needed for engineering projects in irrigation, power, flood control, supply of drinking water and road building; and for projects in the industries, transport and communication sectors. In these pre-planning, design and feasibility tasks, which cost about 3 per cent of the project budget, it has been computed that 5,000 graduates and 5,000 diploma engineers can be employed. In the small-scale industrial sector, particularly for projects in plastics, chemicals, electronic goods, some electrical appliances and food processing, some 5,000 engineers could be employed so that they can bring to the projects, the skills in innovation and adaptation, cost control and market assessment, that this sector needs. The financial aid to engineers, presently a bottleneck for those entering the small industries sector, could be assured by joint action by the Development Commissioner of Small-scale Industry and the Ministry of Industrial Development, working with the states and scheduled banks. Another employment resource would be the use of the growing engineers' cooperatives for public construction work and the re-direction of some of the unemployed engineers into the growing area of agricultural engineering — a new avenue now opening for the country.

Industrial service — Financial subventions from government to the private and public sector in order to provide the new graduated unemployed engineer with adequate periods of practical industrial and specialized training may also be envisaged. The Ministry of Education's industrial training scheme could be expanded for 1968-69 from the present 800 graduates to the 5,000 recommended by the Education Commission, concentrating the increase mainly on diploma holders, whose unemployment is five times that of degree engineers. The expanded training scheme, for instance, could meet the need of thermal stations for some 2,000 engineers and that of the Development Commissioner of Small-scale Industries, who could also assist in their placement, guide their training and arrange for management courses.

Promotion of mobility — Specialization is, in a sense, inimical to mobility. How then can the demand for narrow specializations and the objective of inter- and intra-state and manufacturing industries mobility be reconciled? One way would be for all engineering institutions — university and polytechnic level — to reserve a certain proportion of their intake for students from other states. This would contribute to mobility. Equally, the development of narrow specializations should be limited to those institutions which are located near large urban and industrial centres which both produce a greater desire for movement as between industries and states, and offer employment opportunities for narrow specializations. However, overemphasis on narrow specialization should be avoided as it causes rigidity in manpower supply and such rigidities act as fuel to unemployment in view of rapidly changing technologies which characterize the engineering sector. What is needed is increasingly broad-based curricula which promote flexibility, inventiveness and intuitive adaptability.

In particular, every effort should be made to promote inter-state and intra-state mobility of diploma engineers and technicians, so that the area and state development policies and all employment opportunities are fully and adequately used.

Filling vacancies — A greater effort should be made for filling existing vacancies with more speed and for improving procedures, including dropping the unreal demand for the highest qualifications for every job, for the appointing of engineers to these vacancies. Currently, the average period required for such appointments is 6 months or more. Further, the salary levels of engineers in the public sector and particularly of teachers in engineering institutions need raising, as recommended by the Education Commission.

Short-term planned brain drain — Finally, a personal suggestion. Some temporary migration of unemployed qualified engineers wherever job opportunities await them might be desirable. This could be a short-term five-year planned 'Brain Drain'. Such action might also be a contribution by India towards the industrial development of the other developing countries.

I would like to end with relating the long-term and short-term perspectives. The national income for the current year is likely to rise from the lower levels of the last two years to that of 1964-65. But given the population increase of 7·5 per cent in the intervening three years, an improvement in per capita income for 1973-74 demands a larger size plan than the draft Fourth Plan. This means five more years of belt-tightening. On the assumption of a larger than the draft Fourth Plan, the coming year, 1968-69, could be *the link year* between the recent past of economic stagnation and the future five-year development envisaged. This demands a stepping up of the annual plan figure for the link year 1968-69 and directing the increased investment to the engineering-intensive sectors.

Implications for Unesco and the United Nations System

This facet of Indian economy — the training of engineers and the problem of unemployment that some of them face today — has implications for the United Nations family.

Evaluation — There is need for a careful evaluation of the vast training programme of the country and for basing the programme more closely on precise manpower estimates as the various committees and commissions have recommended. This evaluation is being undertaken and the first decisions on training programmes for the next academic year have been made. This is an area in which the United Nations would be well advised to limit itself to providing advice on request, because the governmental authorities are perfectly able to undertake this task and because this training facet is part of the larger national picture of priorities, including defence. Equally, it makes no sense for the United Nations family to proceed to the evaluation of the small training component it is aiding. This would be looking at a part, without relation to the whole and will inevitably lead to wrong conclusions. In any case, as the United Nations family is associated with a few of the quality institutions, its investment in the country is productive and safe.

Expansion — The programme of the United Nations family, and particularly that of Unesco, in helping the government in the expansion of engineering education facilities is now completed for the next year or two; further expansion must await future economic development. This will involve, for 1969-70, some change in United Nations family priorities for India.

Curricular and quality demands — Aid will be needed in developing post-graduate facilities, in building or strengthening an industrial research and counselling programme in every major engineering institution and in providing education and training in the specialized fields which are still in short supply. Here the Unesco programme of cooperation with the Advanced Centres of Study of the University Grants Commission and the secondary school curriculum reform of the National Council of Educational Research and Training provide pointers. Unesco could cooperate with the government in developing centres of excellence among the engineering institutions and in aiding with teacher training and curricular improvements. The immediate future for Unesco is through cooperation in improving the quality of engineering education in the country.

Wider uses of engineers — UNIDO, ILO and FAO could associate themselves in the wider and more imaginative use of engineers now being planned — engineers establishing small industrial units of their own, starting or participating in industrial estates, further development of agro-industries in the rural centres, etc.

Reducing diversions — The United Nations family has done little in the face of the agricultural crisis faced by the country. It was through the urging and initiative of Unesco that FAO joined with it in aiding India in developing first a farmers' training programme and second a post-graduate agricultural sciences programme, both of which are going through interminable procedural delays. Every month's delay of course means that the problems are being met without United Nations cooperation. Everything that the United Nations family can do to help the government meet the agricultural crisis — not just leave the problem to the government and bilateral assistance — will help in bringing back resources to the manufacturing sector. Even beyond, anything that the United Nations can do to help relieve tensions in the area and promote the next steps towards disarmament will again re-deploy resources towards industrial development.

The education, scientific and communication scene — The Education Commission's recommendations call for sustained action by Unesco in the field of educational planning and training of planners and administrators, in reform and upgrading of science curricula and teachers and improvement and intensification of science teaching and research at the universities. In particular, Unesco should now turn to work with the government on its research programmes through CSIR and ICAR, and advise UNDP to channel parts of its pre-investment resources for India in this direction. In the communication field, particularly in the project for a telecommunication satellite, its engineering, technical and educational aspects, there are vast and exciting possibilities for cooperation. This could be a large and untapped area for the use of unemployed engineers — after some further training.

Family planning and development — There is need for a concerted United Nations Agencies cooperative programme in family planning — with WHO taking the leadership and UNICEF, FAO, Unesco, ILO and the United Nations playing their complementary parts. Without a break on the population expansion, there will be more unemployment and more discoordination.

Integration — Similarly, there is need for the IBRD and the United Nations family, including UNIDO, FAO, Unesco and ILO, to cooperate in new ways with the government in assuring the integration of all facets of the economy for the single purpose of assuring an improved level of living for the people.

Oxidation Mechanisms in Condensed Systems*

SEKHARIPURAM V. ANANTAKRISHNAN
Department of Chemistry, Madras Christian College, Tambaram, Madras 59

CONSIDERABLE amount of work has been done on oxidation and reduction reactions, but the mechanism of these reactions continues to be baffling in several ways. A reducing agent has to transfer electrons to the oxidizing agent in the course of the change and it is in accounting for the manner in which such a transfer takes place that there is uncertainty and differences in point of view. Any mechanism which ignores the role of environment will not represent a true picture of reactions in condensed phase and in particular in solutions.

Role of Redox Potential

One of the commonest factors which can be expected to give us some information on the process is the redox potential. A difficulty in the use of this property, however, is the idealized condition under which alone it can be significant. In aqueous systems and in systems containing water as one of the components, we have to deal with solvated ions which need not have the same shapes or environment in the oxidized and reduced states. Where one of the reactants involves the solvated hydrogen ion even the reversibility of the process may be an uncertain factor. In reactions in which one or both the reactants are ionic, the role of ionic strength and the presence of apparently unreactive ions will have to be considered. Any postulated mechanism which does not take all the factors into account thus becomes open to doubt. A few examples of the uncertainties in redox potentials as an indication of the oxidation process are presented in Table 1.

It is obvious (Table 1) that the nature of the environment plays a part in the magnitude of the potential. Even with the same molality, complexing anions which can substitute in an aquo-complex and the effect of complexing in changing the central metal atom from a cationic to an anionic complex to a greater or less extent appears to play a part in the redox potential. The instances of Cr(VI)-Cr(III) system and Ce(IV)-Ce(III) are particularly interesting variations. The first one is not a thermodynamically reversible system and the transfer of three or six electrons cannot be through any single step. The work of Anantakrishnan and Satyabhama[2] on this system in water and in deuterium oxide indicates an ionic strength dependence of the potential which itself appears to be given more appropriately by Eq. (1)

$$E = E_0 - \frac{RT}{nF} \log [H^+]^2 [HCrO_4]^- / [Cr(III)]^{3+} \quad \ldots(1)$$

TABLE 1 — REDOX POTENTIALS INVOLVING SOME OXIDIZING AGENTS[1]

Redox system	Medium	E_0 at 25°C. V.
*$Ce^{iv} + e \rightleftharpoons Ce^{iii}$	$HClO_4$ 1M	+1·70
	HNO_3 1M	+1·60
	H_2SO_4 0·5M	+1·44
	HCl 1M	+1·28
	K_2CO_3 2·5M	+0·06
$HCrO_4^- + 7H^+ + 3e \rightleftharpoons Cr^{3+} + 4H_2O$	$HClO_4$ 0·01 – 0·1M	+1·2
$H_2O_2 + 2H^+ + 2e \rightleftharpoons 2H_2O$	Aqueous solution	+1·77
$O_2 + 2H^+ + 2e \rightleftharpoons 2H_2O_2$		+1·229
$O_2 + 4H^+ + 4e \rightleftharpoons 2H_2O$		+1·23†

*Values for this system differ from the ones given in Conway, *Electrochemical data* (Elsevier Publishing Co. Inc., Amsterdam), 1952.

†Value given by Fallab, *Angew. Chem. Int. Edn*, **6** (1967), 496.

When the dielectric constant of the medium is lowered, ion-pair formation is to be expected and the oxidized state is better represented possibly by $H_3CrO_4^+$. In the latter case, the least complexing group in perchloric acid gives the highest potential at the same molality of the added acid. In these instances, one has to visualize an electron transfer involving a bridging group which may be water or the anion present in solution. A similar situation exists in other one-electron transfer reactions or two-electron transfer processes[3].

Role of Geometry of Reactants

Chromic Acid Oxidations

One aspect of mechanistic studies to which adequate consideration is not often given is a consideration of the geometry of the reactants, the transition state and the products besides the varying degrees of solvation in the three phases of a reaction. In the initial stages of chromic acid oxidations, a tetrahedral disposition of atoms or groups has to be visualized while the final product of reduction has to have an octahedral configuration. The intermediate stages in the oxidation of the chromium species must necessarily have either a square pyramid or a trigonal bipyramid configuration and because these are unstable oxidation stages of the element, no direct means of establishing this are available.

While it is generally agreed that the rate determining step involves a C-H bond in the organic compound and also a two-electron transfer[4,5], there is no agreement on the mechanism. The postulate of Westheimer that there is the formation of a

---

*Inaugural talk delivered at the Symposium on Reaction Kinetics held during the 55th Indian Science Congress at Varanasi during 1-9 January 1968.

chromate ester with the subsequent removal of a proton from the organic compound is the one accepted by the recent monographs[6,7], but this ignores some very relevant considerations. The recent observation of Wiberg[8] that isopropyl alcohol forms an ester does not necessarily prove that to be an essential stage in the oxidation of secondary alcohols. If ester formation is relevant, the rates should show some relation between the oxidation and the esterification. The trends on substitution effects are precisely the opposite in the two cases[9]. It is often assumed[10] that Cr(IV) first formed reacts with Cr(VI) to form Cr(V) which then reacts with the substrate for oxidizing other molecules. Our own observations with aldehydes[11] (Anantakrishnan, S. V. & Varadarajan, R., unpublished data) indicated a possible alternative and reports on alcohol oxidations carried out similarly in the presence of complexing agents (Venkatasubramanian, N., private communication) supports this further. It is apparent that in the presence of complexing agents, the reaction takes the path Cr(VI) $\rightarrow$ Cr(IV) $\rightarrow$ Cr(II) $\rightarrow$ Cr(III) and the stoichiometry is not materially altered. There is no reason to assume that this path is absent in the absence of the complexing agent. Unless the chromic acid used is in large excess, the chances of Cr(IV) reacting with the substrate are as good as those of Cr(VI). This can also be taken as an indication that the configuration of Cr(IV) is closer to the final product and is probably of the trigonal bipyramid type.

The observations of Tong and King[12] as well as those of Teggins *et al.*[13] clearly indicate that Cr(IV) is as good an oxidizing agent as Ce(IV) so that the alternative path suggested in the oxidations of alcohols and aldehydes cannot be ruled out. Tong and King's work[12] also indicates a possible difference in the coordination number between Cr(IV) and Cr(V) as a cause for the slower oxidation of Cr(IV) to Cr(V). This further strengthens the case of the alternative path to Cr(II) in a two-electron transfer reaction.

Cerium(IV) Oxidations

A difficulty in the interpretation of Ce(IV) oxidations is the complications arising due to dimerization, hydrolysis and association with Ce(III) (ref. 14). The formation of complexes with both sulphate and nitrate ions have been reported by Penney and Anderson[15] and the coordination number appears to be eight rather than six. This permits a sp^3d^4 hybridization to have a dodecahedral or square antiprism geometry[16] and under conditions of complex formation in solution the ligands may be expected to have this arrangement around the central cerium atom. Where concentrations are low, dimers can be excluded. All observations clearly indicate a one-electron transfer in all oxidations, but there is inadequate attention to the correlation between structure of the reducing agent and the reaction rate through systematic variations of this parameter, keeping all others constant.

Among the most thoroughly studied oxidations with Ce(IV) are those with aliphatic ketones where complications are still to be resolved. Enol mechanisms have been proposed by several workers[17,18] but these differ in their stoichiometry. Also this is inconsistent with Littler's report[19] of a faster oxidation than enolization in the case of cyclohexanone. Deuterium isotope effect clearly shows the rate determining step to involve the α-C-H hydrogen and the difficulties in tertiary alcohol oxidation becomes understandable.

Permanganate Oxidations

Permanganate oxidations are of interest in other ways. If the final product of reduction is Mn(II) as is to be expected in strongly acid solutions, we have to reckon with a transfer of five electrons, but if the final product is Mn(IV) which will be the position with excess permanganate, we have a change of three electrons. In these reactions there is a change in the geometry of manganese from tetrahedral to octahedral taking the common forms in these oxidation states. As mentioned earlier, neither change can be in a single step and most of the postulated steps are conjectural than proved. Changes in hydrogen ion concentrations are different and where buffers are used, the reported results can be accepted only where there is no separation of manganese dioxide unless there is evidence to suggest that this does not introduce any complication of heterogeneity in the reaction. The present accepted mechanism is similar to the ester formation of chromic acid for the reaction in acid solutions. This does not explain the changes in hydrogen ion concentration during the reaction except in the presence of buffers which mask such a change. In any case different processes for alcohol oxidations, aldehyde oxidations and oxidations in alkaline media[20,21] have to be thought of. There appears to be reasonable grounds for two-electron transfers in the acid reaction, but the position is by no means satisfactory in alkaline solutions. Polish work quoted by Balandin[22] indicates a series of one-electron transfers in the reaction and at higher concentrations of alkali, the real oxidizing agent appears to be the hydroxyl radical rather than the permanganate ion. The same conclusion appears possible from the work of Kenyon and Symons[23]. When one considers the geometry of the reactants, if an ester-like intermediate is formed, the subsequent loss of a proton from the C-H bond cannot be to the MnO_3 unit which is formed by the hydrolysis of the C-O-Mn system as the distances involved for the hydrogen will be too long. Another reason for considering the geometry of the reactants is that the bonds involved in the oxidation-reduction reactions undergo changes in both the reactants, and the transition state must necessarily involve energy terms taking note of this with an intermediate configuration.

Role of Solvent

In considering the reactions in solution, whatever procedure is adopted, the solvent has to be considered a participant and this is more so when one of the reactants is a charged species. In all the oxidants considered above, the species is charged and the reaction is between this species and a dipole in the organic compound. Any postulated mechanism which ignores this aspect is inadequate. The oxidations with chromic acid brings this out very clearly. It should also be borne in mind that while the hydrogen atom can be both an oxidizing and a reducing agent, the proton whether solvated or not can be only an oxidizing agent while the hydride ion is only a reducing agent. Even though the bulk dielectric constant does not give a complete picture of the position in the reaction region, it is none the less useful as a diagnostic tool and the trends in reaction with changing dielectric constant by the use of mixed solvents is of help. Under these conditions, it is clear that whether it is alcohol oxidation or aldehyde oxidation, the oxidant in chromic acid oxidations in acetic acid-water system especially with larger proportions of the organic solvent is a cationic species[24], and Rocek[25] is obviously wrong in ignoring this aspect. Changes in acidity functions alone are inadequate and in any case where the acetic acid concentrations are large, the values of acidity functions themselves are uncertain[26]. The assumption of high degree of hydration of aldehydes in interpretation of Rocek[25] is also not warranted by facts. It is only formaldehyde that is fully hydrated while higher aldehydes show only slight hydration and aromatic aldehydes still less so. One aspect of solvent influence can be seen by studies in deuterium oxide. In the alcohol oxidations, Westheimer and coworkers report an acceleration in rate in heavy water while Venkatasubramanian (private communication) finds a lower rate in this solvent. In our study of redox potentials of the Cr(VI)-Cr(III) system, it is found that there is a definite lowering of the potential in changing to deuterium oxide and this suggests a lowered rate of oxidation in this solvent. Similar results are also found with aldehyde oxidations (Anantakrishnan, S. V. & Satyabhama, V., unpublished data). Further work is clearly called for. Whether one considers the effect of substitution or the effect of solvent, it is clear that in the rate determining step in chromic acid oxidations, the transition state involves an electron deficient carbon[24].

Turning to inorganic systems, we have a different situation. In aqueous solutions, participation by water molecules has to be considered in the different stages of the reaction and where there is a change in the hydrogen ion concentration during the reaction, the role of this has to be taken note of. Geometries of the reactants become even more significant than in the organic reactions. Further, the stabilization of higher oxidation states by ligands which form σ-bonds and the opposite effects by ligands forming π-bonds has also to be reckoned with[27]. At the same time the stability has to be related to the environment. It is generally observed that where the oxidizing agent is an oxyanion, in aqueous solution an acid is essential, and even in the case of bromate it has been suggested that the oxidizing agent is $H_2BrO_3^+$ or $H_2O+BrO_2^+$ (ref. 30). Where the reaction involves an electron transfer from one metal to another with both reactants being aquo-complexes, a bridging mechanism involving a hydrogen atom in the ligand is usually thought of. There is no reason why this transfer should not involve a solvated electron since it has been observed that the behaviour of a solvated electron is similar to that of hydrogen[28,29].

Isotope exchange and electron transfers are among the types of reactions in which considerable work has been done. The importance of geometry is well brought out in these reactions. It is generally found that where the two reactants have similar geometry so that a symmetrical transition state is possible, the exchange reaction is very fast while it is slow where the geometries are different. A further complication in these reactions is that the dimensions of the molecules need not be the same in the different oxidation states. This very difference together with the differences in solvation energy lead to an activation energy modifying the rate of reaction. The role of solvent in exchange reactions is shown by studies on the Fe(II)-Fe(III) system in dimethyl sulphoxide[30]. A peculiar behaviour of the reaction is an extremely fast reaction in the presence of very small amounts of perchloric acid and a measurably slow reaction at higher concentrations independent of the perchloric acid concentration. This needs confirmation and an explanation in terms of possible mechanisms.

Electron transfer processes are even more relevant to the subject matter of this article. An aquo-complex of the oxidizing agent can lead to another in which the metal is in a lower oxidation state with the formation of a free hydroxyl which functions as the real oxidant. This has been suggested as a possible mechanism in the reaction between Ce(IV) and Tl(I) (ref. 31). Bridging with a ligand is found to be quite a normal feature of Fe(III) oxidations and possibly also of Cu(II) (ref. 32-34). Examples of the first are provided by Fe(III) oxidations of sulphites and hydrogen peroxide, while the action of Cu(II) is exemplified by the oxidation of aniline to hydrazobenzene[35].

Scope for Further Work

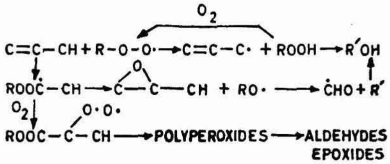
An aspect of chromic acid oxidations which requires re-examination is the effect of complex formation by $HCrO_4^-$ ions with hydrogen phosphates, bisulphates and even chlorides[36,37]. It is also necessary to elucidate mechanisms of reactions in which a transition metal ion functions as a catalyst for an oxidation that does not take place when only the oxidant and reductant alone are present. Such reactions can be expected to give information about intermediate oxidation states of a transition metal oxidant[37]. Where oxyanions function as the oxidizing agents, it is possible that at least some of the reactions involve an oxygen transfer. At present the only available technique for the study of such processes involve the use of isotopic oxygen and it will be worth while finding some alternative means of establishing such mechanisms. In permanganate oxidations, some at least involve an oxygen transfer and the rapid exchange between manganate and permanganate ions involve such a bridging. It is significant that this exchange shows specific cation effects[31,38] and rate studies as a function of acid concentration indicate the possible formation of H_2MnO_4 (ref. 20). It is clear that this species will have to be considered in oxidations of acid permanganate as well. (The more rapid oxidations of halide ions in acid permanganate when compared with alkaline permanganate is an indication of this.)

In using isotope effects, whether primary or secondary, some caution is necessary. It is possible to visualize alternative paths of comparable energy in exchange reactions especially with transition elements. This is specially the case of oxidation-reduction systems where a bond involving hydrogen is studied. This will be the position in aqueous and other hydroxylic systems. The chromate ion and the permanganate ion show different mechanisms of isotope exchange. Steric problems of the aquo-complexes in relation to oxygen exchange are provided by the differences shown by Ni^{2+}—aq., Fe^{3+}—aq. and Al^{3+}—aq. even though in all the three cases the first coordination sphere of the cation is involved[39]. Reductions by lower valence state transition metal ions should similarly take into account a possible competing reaction involving a solvated electron. It has also to be remembered that even where the geometries of the two oxidation states involved in the exchange reaction are the same, different ionic sizes will make the transition state slightly unsymmetrical.

It is also necessary to bear in mind that both in oxidation-reduction reactions and exchange reactions involving ions, ion association is to be expected where the concentrations are in the range of the Bjerrum distances between the ions. It is also possible that ion-pair formation is the rate determining step in the reaction[40].

An important group of oxidation reactions in recent work is the use of molecular oxygen as the oxidant with a transition metal as a catalyst. In spite of an apparently favourable redox potential and the presence of two unpaired electrons on the oxygen molecule, reactions with this oxidant happens to be relatively slow. The reaction is one which involves several steps with HO_2, OH and H_2O_2 as intermediates. In auto-oxidation processes these intermediates are often involved. The development of rancidity of oils and the drying of oils are two aspects which have received a good deal of attention, but mechanistic studies have been comparatively recent and offer a rich field. In both types of reactions and even in the simpler auto-oxidation of benzaldehyde and related substances, heavy metal ions of the transition series have been recognized to play a significant part. Interest in these reactions is from the point of biogenesis, variety of products and steric course. Silver catalysed oxidation of ethylene to ethylene oxide is a precursor for the formation of other epoxy compounds. The formation of ketones, oxidations of C-H linkage to carboxylic acids, formation of hydroxy derivatives are all reactions of current interest with the development of the petrochemical industry in the country and the synthetic fibre and plastics industry. A mechanistic study of the relevant reactions will be one of the aspects of import substitution on which we can devote some attention.

Martell and Calvin[41] have shown from the study of a variety of chelate compounds of cobalt(II) peroxy compounds of the type CoO_2^{2+} which are possible intermediates in other oxidations. This can involve the formation of polynuclear intermediates of the type recently reported for the oxidation of ethanol by hydrogen peroxide in the presence of $Fe(III)^{3+}$ (ref. 42). In the case of olefine oxidations, it has been generally observed that complex formation as a prelude to further reaction is often associated with d^8 and d^{10} atoms or ions but the role in rate studies is yet to be satisfactorily elucidated. Brill[43] has postulated for the auto-oxidation the following mechanism:



The mechanism does not take into account the catalytic effect of transition metal ions. The role of solvent in these oxidations also needs elucidation. A study of the effect of substitution will be needed to see whether, as has been sometimes assumed, the peroxy radical is electrophilic in its reactions. Oxidations are largely dependent on the medium as well as other environment and both one-electron and two-electron steps have been proposed[44]. All the observations so far are suggestive of further work in the field. As with other reactions, geometry of the intermediates seems to play an important role and calls for further work[45].

Summary

Among common chemical reactions, oxidation figures extensively and several oxidants are used. The mechanism of the process is still far from clear. The various factors to be taken into account in formulating mechanisms in solution are considered for oxidations using chromic acid, permanganate and ceric compounds. The inadequacy of redox potentials, the role of solvent, the geometry of the reactants and products and the differences noticeable with organic and inorganic reducing agents are briefly reviewed. A new field of study suggestive of further work in the country taking into account industrial processes using atmospheric oxygen as the oxidant has been indicated.

References

1. CHARLOT, G., BÉZIER, D. & COURTOT, J., *Oxidation-reduction potentials* (Pergamon Press Ltd, London), 1958, 9, 10, 21.
2. ANANTAKRISHNAN, S. V. & SATYABHAMA, V., *Solvent isotope effects in chromic acid oxidations*, Radiation chemistry symposium, Poona (Department of Atomic Energy), 1967.
3. DUKE, F., *Mechanism of inorganic reactions* (American Chemical Society), 1965, 224.
4. WATANABE, W. & WESTHEIMER, F. H., *J. chem. Phys.*, **17** (1949), 61.
5. ANANTAKRISHNAN, S. V. & VENKATASUBRAMANIAN, N., *Curr. Sci.*, **27** (1958), 438; *Proc. Indian Acad. Sci.*, **50A** (1959), 156.
6. *Oxidation in organic chemistry*, edited by F. H. Westheimer (Academic Press Inc., New York), 1965.
7. WATERS, W. A., *Mechanism of oxidation of organic compounds* (Methuen & Co., London), 1965.

8. Wiberg, K. B., *J. Am. chem. Soc.*, **89** (1967), 455.
9. Anantakrishnan, S. V. & Venkatasubramanian, N., *Proc. Indian Acad. Sci.*, **50A** (1959), 310.
10. Cohen, M. & Westheimer, F. H., *J. Am. chem. Soc.*, **74** (1952), 438.
11. Anantakrishnan, S. V. & Jayaraman, H., *Indian J. Chem.*, **2** (1964), 146.
12. Tong, J. Y-P. & King, E. L., *J. Am. chem. Soc.*, **82** (1960), 3805.
13. Teggins, J. E., Wang, M. T. & Milburn, R. M., *Reactions of coordinate ligands and homogeneous catalysis* (American Chemical Society), 1963, 239.
14. Dorfman, M. K. & Gryder, J. W., *J. inorg. Chem.*, **1** (1962), 799.
15. Penney, W. G. & Anderson, J. S., *Trans. Faraday Soc.*, **33** (1937), 1363.
16. Duffey, G. H., *J. chem. Phys.*, **18** (1950), 741, 1444.
17. Venkatakrishnan, S. & Santappa, M., *Z. phys. Chem.*, **16** (1958), 73.
18. Shorter, J., *J. chem. Soc.*, (1962), 1868.
19. Littler, J. S., *J. chem. Soc.*, (1962), 832.
20. Stewart, R., in *Oxidation in organic chemistry*, edited by F. H. Westheimer (Academic Press Inc., New York), 1965, 24, 48, 52.
21. Waters, W. A., *Q. Rev. chem. Soc.*, **12** (1958), 277.
22. Jezowska-Trzebiatowska, in *Catalysis and chemical kinetics*, edited by A. A. Balandin (Academic Press Inc., New York), 1964, 217.
23. Kenyon, J. & Symons, M. C. R., *J. chem. Soc.*, (1953), 3580.
24. Wiberg, K. B., *J. Am. chem. Soc.*, (1967), 165.
25. Rocek, J., in *Chemistry of carbonyl compounds*, edited by S. Patai (Interscience Publishers Inc., New York), 1966, 461.
26. King, E. J., *Acid base equilibria* (Pergamon Press Ltd, London), 1965, 318.
27. Basolo, F. & Pearson, R. G., *Mechanism of inorganic reactions* (John Wiley & Sons Inc., New York), 1958, 320.
28. Hart, E. J., *Science, N.Y.*, **146** (1964), 19.
29. Walker, D. C., *Q. Rev. chem. Soc.*, **21** (1967), 79.
30. Menashi, J., Reynolds, W. L. & Van Auken, G., *J. inorg. Chem.*, **4** (1965), 299.
31. Halpern, J., *Q. Rev. chem. Soc.*, **15** (1961), 207.
32. Karrakar, D. G., *J. phys. Chem., Ithaca*, **67** (1964), 871.
33. Kremer, M. & Stein, G., *Trans. Faraday Soc.*, **55** (1959), 959.
34. Haggett, M. L., Jones, P. & Wynne-Jones, W. F. K., *Discuss. Faraday Soc.*, **29** (1960), 153.
35. Kinoshita, K., referred to by Anbar, M., *Mechanism of inorganic reactions* (American Chemical Society), 1965, 129.
36. Lee, D. G. & Stewart, R., *J. Am. chem. Soc.*, **86** (1964), 3051.
37. Haight, G., *Mechanism of inorganic reactions* (American Chemical Society), 1965, 179.
38. Grierson, L. & Wahl, A. C., *J. Am. chem. Soc.*, **81** (1959), 1572.
39. Taube, H., *Progress in stereochemistry*, edited by P. B. de la Mare & W. Klyne (Butterworths Scientific Publishers, London), 1962, 107.
40. North, A. M., *The collision theory of chemical reactions* (Methuen & Co., London), 52.
41. Martell, A. E. & Calvin, M., *Chemistry of metal chelate compounds* (Prentice-Hall Inc., New York), 1952, Chapter 8.
42. Heitler, C., Scaife, D. B. & Thompson, B. W., *J. chem. Soc.*, Section A (1967), 1409.
43. Brill, W. F., *Selective oxidation processes* (American Chemical Society), 1965, 70.
44. Fallab, S., *Angew. Chem. Int. Edn*, **6** (1967), 496.
45. Erden, B. & Fallab, S., *Chimia*, **19** (1965), 463.

Seminar on Electrochemistry

The Ninth Seminar on Electrochemistry will be held at the Central Electrochemical Research Institute, Karaikudi, during 26-29 December 1968. The topics of discussion at the different technical sessions will be: (i) Electrode kinetics — electrochemical equilibria and electroanalysis; (ii) Solid state electrochemistry; (iii) Corrosion; (iv) Electrodeposition and metal finishing; (v) Batteries; (vi) Electro-organic and electro-inorganic products; and (vii) Electrothermics and electrometallurgy. There will also be a special session on "Electrochemical industries and the Fourth Five Year Plan of India". Further details can be obtained from Shri B. A. Shenoi, Convener, Ninth Seminar on Electrochemistry, Central Electrochemical Research Institute, Karaikudi 3.

A technical session on "Electrochemical production of metal powders and their applications", organized by the Society for Advancement of Electrochemical Science and Technology, will be held at the Central Electrochemical Research Institute, Karaikudi, on 28 December 1968. Further details can be obtained from Dr K. S. Rajagopalan, Secretary, Society for Advancement of Electrochemical Science and Technology, Central Electrochemical Research Institute, Karaikudi 3.

Self-assembly of the Protocell from a Self-ordered Polymer*

SIDNEY W. FOX
Institute of Molecular Evolution, University of Miami, Coral Gables, Florida, USA

THE problem of the origin of life, or in truly perceptive nineteenth century terms, the problem of spontaneous generation, has often been regarded as one of overwhelming complexity. Upon analysis, with the aid of hindsight, this problem loses some of its imponderability. The aspect of evolution which first received major attention was that of the progression, in principle, from primitive cell to contemporary cell and to contemporary multicellular organisms. This stage is the one that has been illuminated mechanistically by Darwin's theory of selection. We can now regard this stage as far more intricate and involved than the emergence of primitive life from the primordial reactant gases. By such an analysis, the primordial cell is emphasized, the highly ramified later stages are removed from purview, and the limits of the meaningful problem are identified.

The preorganismic stage can also be analysed. For intellectual convenience, it may be divided into two or three parts. The first of these parts is that of the spontaneous organic synthesis involved in the production of the small organic molecules which are necessary for contemporary and, presumably for, primitive organisms. The second step is the spontaneous synthesis of the polymers and of cells. This latter constitutes in turn, however, two stages. These two steps were collectively most forbidding in quality, and are particularly significant to life and, therefore, to its origin. Our most modern knowledge requires that we recognize that a primitive cell cannot be a synthesized entity in the true meaning of 'synthesized'. The precursor macromolecule can be conceived of as synthetic. When the appropriate macromolecule has been formed, the final and crucial stage, leading to a primitive organism, would then be one of self-assembly. The term 'self-assembly' and the concept have recently been receiving increasing recognition, e.g.[1] in the biochemistry of contemporary systems.

One way in which students of the total problem have dealt with the seemingly great complexity has been to postulate a long chemical evolution[2] extending over, say, 25 million years. I will explain here why our experiments lead to the interpretation that the essential steps from primordial gases → amino acids → primitive protein → a primitive organized structure having simultaneously many life-like properties, including the ability to participate in its reproduction, could have occurred many times in a very short period, say 25 hr.

Our approach to this problem was based on clues from contemporary cells. The results of experiments have been evaluated in part by how well they lead to an increasing appearance of the properties that are associated with contemporary cells. The experiments have, however, been based on very simply derived initial systems and simple processes. These employ conditions that have proved to be plausible not only for geologically ancient times; the conditions identified are widespread now and through recorded history[3].

Models of the prebiotic synthesis of small organic compounds, such as monosaccharides, amino acids, purine and pyrimidine bases, ATP, porphyrins, etc., have been described from many laboratories, including those of Ponnamperuma[4], Oro[5], Ferris and Orgel[6] and our own[7]. Since the essence of life is generally recognized as being that of the biopolymers, protein and nucleic acid, this paper will focus on questions involving the primordial formation of protein and nucleic acid and on the attributes of the polymers formed in the laboratory. It will deal also with complexes of the two.

Turning first to the question of proteins, we find that a number of studies of the synthesis of peptide bonds, mostly in aqueous solution, have been carried out in a number of laboratories. Akabori *et al.*[8] employed the progressive substitution of polyglycine as a model of the first protein, and Matthews and Moser[9] have reported a similar process. The model of our laboratory which relies on heat and hypohydrous conditions is the only one that has yielded polymers of molecular weight in the thousands, a content of all 18 amino acids common to protein, several protoenzymic activities, and it is the only model which has been demonstrated to yield organized structures with a lengthy roster of the properties of the contemporary cell[10]. This synthesis has the simplicity appropriate to geologically spontaneous occurrences, and it yields both polymer and organized units in abundance.

One other synthesis, which has most of the attributes enumerated, uses as intermediates the reactive Leuchs anhydrides of the amino acids. This synthesis was also first performed in our laboratory by Hayakawa *et al.*[11]. Of these two syntheses, only the thermal process has the simplicity appropriate to geologically spontaneous occurrences.

The thermal syntheses, first attempted in 1953, were indicated as thermodynamically possible following studies of Borsook *et al.*[12]. The results of calculations from the tabulated physical constants have shown that one could expect in an open aqueous solution only small yields of small peptides unless the reaction were somehow coupled to an endergonic one.

The fact that organisms are nearly always aqueous entities has led some to assume that hot, dry conditions would not have been appropriate to early life and they have somehow projected such thinking to precursor molecules. Our chemical experience, however, tells us that macromolecules can easily survive conditions lethal for ordinary cells, and our

---

*Since 1960, this research has been aided by the National Aeronautics and Space Administration, currently Grant No. NsG-689, Contribution No. 096 of the Institute of Molecular Evolution. The article was presented at the International Convention of Biochemists, Bangalore, 7 September 1967.

biological experience reminds us that dry bacterial spores are relatively highly resistant to heat and dryness.

The reaction involving the formation of peptide bond with its attendant Gibbs free energy change is

$$H_2NCHRCOOH + H_2NCHR'COOH = H_2NCHRCONHCHR'COOH + H_2O$$
$$\Delta G^\circ = 2000 \text{ to } 4000 \text{ cal.}$$

As the number of peptide bonds per molecule increases, the equilibrium constant becomes geometrically more unfavourable. Dixon and Webb[13] have calculated that the volume of amino acid solution in equilibrium with one molecule of protein of molecular weight 12,000 would be 10^{50} times that of the earth ! Stated otherwise, uncoupled synthesis from amino acids in water should be expected to give small yields of small peptides only.

In order to shift this equilibrium to favour synthesis, one can postulate removal of either product. Theoretically, one contribution of a membrane in contemporary protein-synthesizing systems may be the overcoming of an energy barrier by the separation of synthesized macromolecules from the aqueous solution. This process could not apply, however, until a membrane composed of macromolecules had first formed. Our attention, therefore, shifts to the removal of the other product, water. This route to peptide bond synthesis can be visualized as a geochemical possibility. It has also been demonstrated experimentally[7].

One mode of removal of water, as suggested by the thermodynamic analysis, would be that of heating the amino acids above the boiling point of water. When this possibility was initially contemplated, the probability of gross decomposition had to be considered. Such a consequence of heating α-amino acids above the boiling point of water has been recorded in the literature a number of times. We were led to attempt the thermal condensation by employing an inference from comparative studies of organismic protein, the fact that the amino acids which most dominate the composition of proteins are glutamic acid and aspartic acid[7]. These contents were taken hypothetically to be an evolutionary reflection of a circumstance required for the primordial formation of prebiotic protein.

Another consideration that had to be dealt with was the somewhat vague feeling that, without the presence of nucleic acids, the necessary systematic sequences of amino acid residues would not result. This problem was conceptually eliminated, in principle, by studies of enzymic acylpeptideanilide synthesis[14], which demonstrated that interactions of amino acid residues would alone select the sequence formed (this principle and the inference that prior nucleic acids may have been unnecessary[7] has since been corroborated by Steinman[15] in another system of reacting amino acids). Since the difficulties were thus conceptually surmountable in 1953, heating was employed. The discussion now deals with experimental observations.

A typical thermal condensation used at first a mixture of 1 part of aspartic acid, 1 of glutamic acid, and 1 of an equimolar mixture of the 16 other amino acids common to protein. This mixture was heated at 170°C. for 6 hr[16]. The resulting light amber glassy product, not depicted, is entirely soluble in water by salting-in, and can be purified by salting-out. Such products yield amino acids 100 per cent by acid hydrolysis, they contain some proportion of each of the amino acids common to protein (or fewer as desired), and molecular weights of many thousands. They have many other properties of proteins and are called proteinoids. The proteinoid described in this example is, because of the proportions reacted, a 1:1:1 type. More recently, Waehneldt has shown in our laboratory that aspartic acid and glutamic acid may be merely equimolar with the 16 other amino acids. Proteinoids are produced even so. Yields in the usual syntheses are typically in the range 10-40 per cent, higher yields being obtained by the addition of phosphates[17,18]. Many other laboratories have repeated this synthesis and have confirmed it and its simplicity, which is in turn crucial to the geological validity. The spontaneous occurrence of a carbobenzoxy synthesis or the formation and condensation of N-carboxy amino acid anhydrides cannot, of course, be defensibly imputed to the geological environment.

The numerous properties which the proteinoids have in common with proteins are described in detail in the literature, and these have been reviewed a number of times[7,10].

Table 1 lists the many simultaneous structural, chemical and biological properties all of which are described in literature cited bibliographically, except for recently demonstrated hormonal activity and a few other aspects. Hence, only three salient properties on which many new data are available are reviewed here: (i) limited heterogeneity and the related question of systematic sequences; (ii) catalytic activity; and (iii) the property of forming regular and highly structured particles.

The first indication that a thermal condensate of 18 amino acids yields no more than two electrophoretic individuals was from a study by Vestling[16].

TABLE 1 — PROPERTIES OF THERMALLY PREPARED PROTEINOIDS

Limited heterogeneity
Qualitative composition identical to that of protein
Quantitative compositions resembling those of proteins
Quantitative recoverability of amino acids upon hydrolysis
Range of molecular weights like those of smaller protein molecules
Positive colour tests as for protein
Solubilities resembling those of protein classes (albumins, globulins, etc.)
Some optical activity
Tendency to be salted-in
Tendency to be salted-out
Precipitability by protein group reagents (phosphotungstic acid, etc.)
Hypochromicity
Infrared absorption maxima as found in protein
Some susceptibility to proteases
Nonrandom distribution of amino acid residues
Many catalytic activities
Inactivatability of catalytic power
Nutritive quality
Melanophore stimulating activity
Morphogenicity

Subsequently, Harada in our laboratory showed that two fractionations of a 2 : 2 : 3-proteinoid from hot water resulted in virtually no change in amino acid composition[19]. Also, N-terminal[16] or C-terminal analyses[20] of many polymers demonstrated marked disparities from the total compositions, indicating that systematic nonrandom sequentialization occurred. This could be due only to selective interactions of amino acids during thermal condensation. Since that finding, many new data obtained by Nakashima and a review of all of the data have been published[21].

The elution pattern from fractionation on DEAE-cellulose is shown in Fig. 1.

While no random assortment of polyanhydro-α-amino acids has been prepared such that a comparison would be possible, we would expect theoretically an elevated nearly horizontal line for an elution pattern of a disordered polymer. What is repeatedly found, instead, is a pattern of six major peaks, of which some are already symmetrical.

For comparison is presented an elution pattern of turtle serum protein[22] also fractionated on DEAE-cellulose. Eight major peaks, with less spread in each peak, are observed. The individual peaks of the eluate sediment in the Spinco model E (Fig. 2) to indicate for the fractions the degree of ultracentrifugal homogeneity which is observed.

Fig. 3 shows the complete and partial hydrolysates of three fractions from DEAE-cellulose. The bottom three are partial hydrolysates in each group. The patterns are highly similar, as can be seen.

A total picture of nonrandom sequences in the linear distribution, discrete macromolecular fractions, and relatively uniform composition and sequences throughout the entire polymer is supported also by high voltage electrophoresis, by separation on columns of Sephadex, by polyacrylamide fractionations, and by gel electrophoresis.

Information on catalytic activity in proteinoids is summarized in Table 2. These findings are from six laboratories and they include catalysis of the hydrolysis of esters and of ATP and decarboxylations of a number of natural substrates[23]. Krampitz has recently recorded an example of amination. Michaelis-Menten kinetics have been reported in several of the studies. The activities are mostly weak. As Calvin pointed out for the iron-containing enzymes[24] and as I pointed out in 1953 (ref. 25) weak primitive enzymic activity would be selected and enriched by Darwinian processes in organisms. Of relevance, also, is the fact that some gross specificities have been identified and that individual proteinoid preparations each have an array of catalytic activities. A metabolic sequence has been recorded, for example, for oxaloacetic acid → pyruvic acid → acetic acid + CO_2.

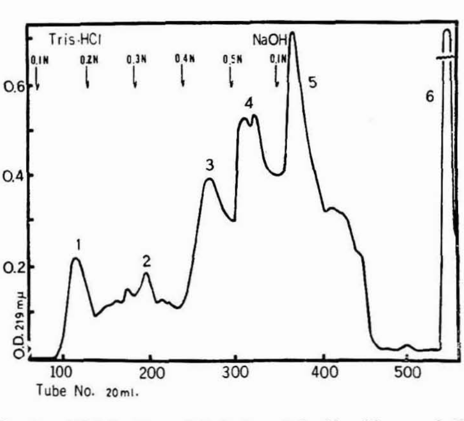


Fig. 1 — Distribution of 1 : 1 : 1-proteinoidamide on elution from a DEAE-cellulose column by tris-HCl buffer (Numbers designate the principal fractions)

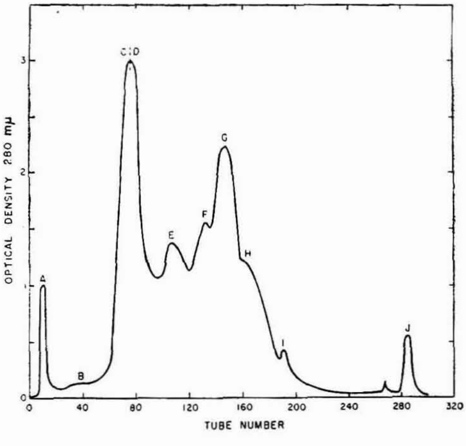


Fig. 2 — Distribution of turtle serum proteins on elution from a DEAE-cellulose column by sodium phosphate buffer (Letters designate the principal fractions)

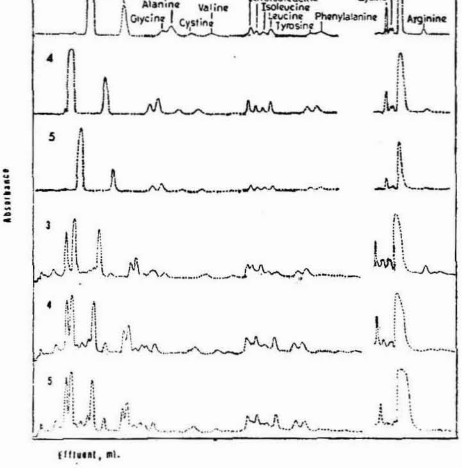


Fig. 3 — Top three profiles of hydrolysates of 3 fractions of proteinoidamide show great similarity in amino acid content. Bottom three profiles show similarity in peptides obtained on partial hydrolysis (Numbers 3, 4 and 5 correspond to the fractions 3, 4 and 5 from DEAE-cellulose as in Fig. 1)

TABLE 2 — CATALYTIC ACTIVITIES IN PROTEINOIDS

Reaction	Salient finding	Ref.
p-Nitrophenyl acetate	$\text{Activity}_{\text{ptd}} > \text{Activity}_{\text{hsd}}$	26
p-Nitrophenyl acetate	Activities	27
p-Nitrophenyl acetate	Inhibition by organic phosphates	28
p-Nitrophenyl acetate	Detailed treatment	29
p-Nitrophenyl acetate	'Active site', and inactivation	30
Glucose → glucuronic acid → CO_2	First natural substrate reported	31
ATP → ADP and others	Biochemical energy source	32, 33
p-Nitrophenyl phosphate	Second phosphate hydrolysis	34
Pyruvic acid → acetic acid + CO_2	Decarboxylation M-M kinetics	33, 35
Oxaloacetic acid → pyruvic acid + CO_2	Catalysed by ptds of type not active on pyruvic acid	36
α-Ketoglutaric acid + urea → glutamic acid	Proteinoid and Cu each needed	37

We can explain the evolutionary potential of polyanhydroamino acid catalysts by the fact that in the same macromolecule are found not only a variety of chemically functional groups, but also the products of interaction of the fields of force of two or more of these groups. This picture of chemical polyfunctionality is also, of course, applicable to proteins and emphasizes what Needham[38] has referred to as 'the uniqueness of biological materials'. Proteinoid is in one sense perhaps even more unique than any one protein in that it is less specialized, and recalls thereby for serious consideration the concept of 'urprotein'[39].

The property of forming structurally organized units on contact with water is crucial to a comprehensive theory of the origin of the first cell. This tendency is intrinsic to many thermal polymers of amino acids, as we reported in 1960. The need for a macromolecular precursor of the first cell has been emphasized in theoretical discussions by Oparin[40], Wald[41], Lederberg[42] and others. The degree to which thermal proteinoid meets this need by providing organized microscopic units having numerous associated properties such as are found in contemporary protein and in contemporary cells could not have been predicted. Only some of the more salient properties will be presented here. Others are documented with references to supporting literature[43]. The properties include, among others, a cellular type of ultrastructure, double layers, abilities to metabolize, to grow in size, to proliferate, to undergo selection, to bind polynucleotides, and to retain some macromolecules selectively. The structures in Fig. 4 are usually produced merely by heating the proteinoid with water or aqueous solution. The clear liquid, on cooling, deposits huge number of microscopic units, 0·5-80 μ in diam., of quite uniform size in any one preparation. These are usually found as spherules, as in this photomicrograph, but they occur also as filaments, budded microspheres, as twinned units, and in other shapes. They are exceedingly numerous; one gram of heated amino acids can produce many billion spherules. As pointed out by us and by others[44], they have physical stability comparable to that of contemporary cells; they can, for instance, be sectioned for electron microscopy. In their uniform size and in other respects, they are readily distinguished from oily droplets or from the known coacervate droplets. While they can be produced as entirely separate units, they also tend to associate[45]. By adjustment of the basic amino acid content, they can be produced to stain either gram-negative or gram-positive[46]. They also have been shown to have some of the catalytic activities which have been carefully identified in the polymer of which they are composed[23].

The ultrastructure of the microsphere is shown in the electron micrograph in Fig. 5. On the left is a section of *Bacillus cereus* which has been fixed by osmium tetroxide, sectioned, and electron micrographed by Murray[47]. On the right is seen a section of a proteinoid microsphere fixed with osmium

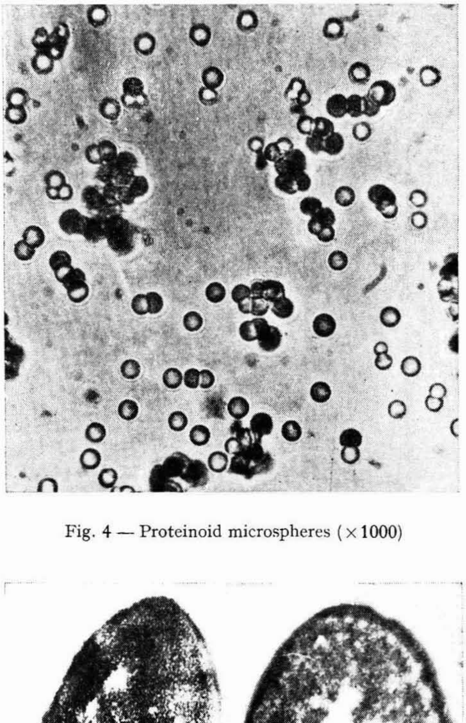


Fig. 4 — Proteinoid microspheres (×1000)

Fig. 5 — Electron micrographs of *Bacillus cereus* (left, ×56000) and of proteinoid microsphere (right, ×16000). Each has been fixed with osmium tetroxide and sectioned

tetroxide and sectioned. While some bacteria reveal a more organized pattern than *Bacillus cereus*, this micrograph reveals only a boundary and granular cytoplasm. The granular appearance is found also in the proteinoid microsphere, and the latter has a more definite boundary. In one place the boundary appears to be a double layer. In the treatment preceding electron micrography (Fig. 6), the polymer in the interior was first caused to diffuse out through the boundary by raising the *p*H in the suspension of proteinoid microspheres by one to two units. Double layers are clearly evident[7]. We can also see part of the results of other phenomena. The diffusion depicted is one manifestation of selective behaviour in the boundary or membrane. This diffusion is further illustrated in Fig. 7, in which the effect was followed by photographing in ultraviolet light through the quartz optics of Dr Philip Montgomery's microscope at the University of Texas.

The proteinoid, like protein[48], absorbs at ultraviolet wavelengths. These pictures and related data indicate that the polymer is not condensing on the membrane, but is passing selectively through a membrane composed of very similar polymer, as has been shown by analysis[49].

Models of primitive polynucleotides have also been examined. In collaboration with Dr Waehneldt, we have reported how nucleoside mono- and triphosphates could have been prebiotically synthesized in quantity[50], following an earlier report on the production of ATP by Ponnamperuma[51]. Thermal polymers of mononucleotides have been shown, by Schwartz, in our laboratory, to be attacked by ribonuclease and by venom phosphodiesterase[52]. Recently, we reported with Dr Waehneldt and others that such polynucleotides, as well as calf thymus DNA and yeast RNA, bind with appropriate proteinoids to yield models of the various nucleoprotein particulates found in the contemporary cell, such as ribosomes, chromosomes, chromatin, etc. (Fig. 8).

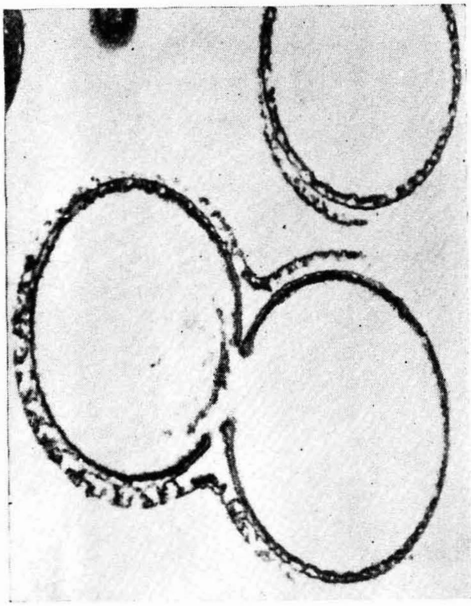


Fig. 6 — Proteinoid microsphere subjected to raised *p*H (×14500). Double layers are evident

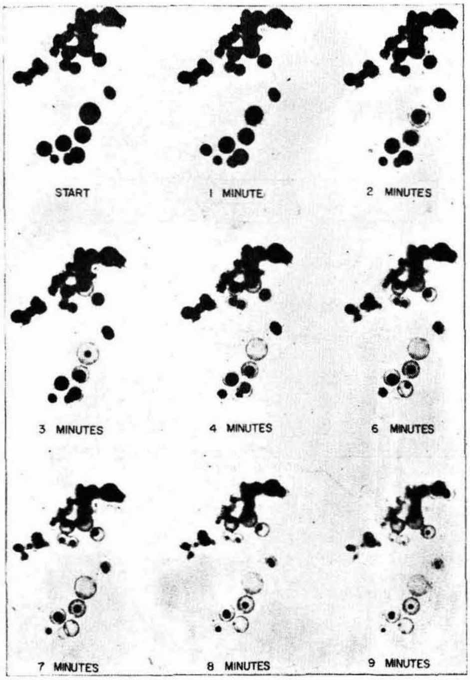


Fig. 7 — Photograph of *p*H effect followed by photograph of ultraviolet effect through quartz optics (×850)

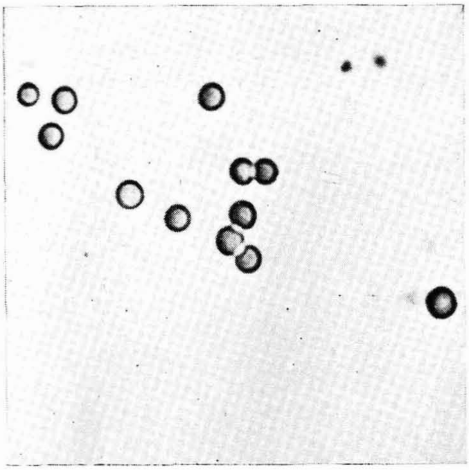


Fig. 8 — Minispheres composed of RNA and lysine-rich proteinoid (×5000)

Fig. 9 provides an example of fibres produced from lysine-rich proteinoid and calf thymus DNA. Very small microspheres result when RNA or thermal polyribonucleotides are used instead of DNA. The ratio of polynucleotide to basic proteinoid in such complexes tends to be quite constant. The fibrous and spherical morphologies are reminiscent of contemporary analogues as in chromosomes and ribosomes respectively. Those proteinoids that bind to form such particles have a ratio of basic amino acid to dicarboxylic amino acid above a minimum of 1·0.

With polyphosphoric acid and temperatures of 60-100°C. experiments in our laboratory have shown that either mononucleotides or amino acids might be polymerized[18,52]. Accordingly, these processes might ordinarily have occurred simultaneously. The suggestion of Calvin that proteins and nucleic acids might have arisen simultaneously in a primordial event[53] is thus consistent with the experimental demonstrations. Although model studies of prebiotic polynucleotides have been pursued, as indicated, a basic question that persists is that of how many properties models of primitive protein systems might display *without* polynucleotides. This question especially deserves to be asked in view of the fact that proteinoids contain their own information and have sharply limited variation without any control by nucleic acids. Also, the self-assembling properties of proteinoid yield ultrastructure, double layers, fission, etc., without nucleic acid control[7]. Can then, for example, proteinoid microspheres multiply without polynucleotides present ? Figs. 10-13 show how in a very simple manner proteinoid microspheres do, in fact, participate in the reproduction of their own likeness[43].

In Fig. 10 are seen a number of proteinoid microspheres which have been allowed to stand in their mother liquor for two weeks. On these are found 'buds' which in appearance resemble buds on yeast. We first observed such buds in 1959. These 'buds' can grow in size, either while attached to the parent microsphere, or after separation. Removal can be accomplished at various stages of growth in size by shock — electrically, thermally, or mechanically. In the first two modes, we believe that some interfacial material is dissolved. 'Buds' are seen in Fig. 11. In order to demonstrate the next event rigorously, the separated buds were stained with crystal violet. When the stained separated buds are allowed to stand in a solution of proteinoid saturated at 37°C., and this is allowed to cool to 25°C., the buds, in an appropriately sized vessel, 'grow' by accretion to the size shown within one hour. The resultant units tend to be very uniform in size; the opposing forces are evidently precisely balanced under any given set of conditions.

In this manner we can visualize how proteinoid microspheres could simply first have developed the ability to participate cyclically in the reproduction of their own likeness. In manifesting such a process, a primitive organized structure would be functioning as a nearly complete heterotroph in that it obtained its large molecules by feeding on the environment instead of synthesizing them itself. Many theorists on the subject of abiogenesis have reasoned that the

Fig. 9 — Photograph of fibrous complex of calf thymus DNA and of lysine-rich proteinoid (× *c.* 190 by darkfield illumination)

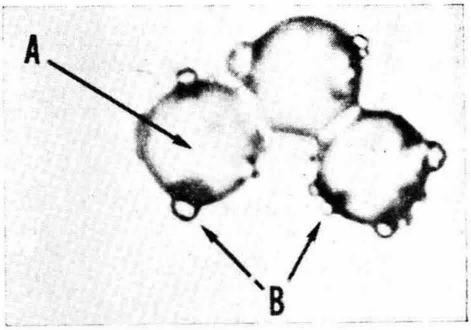


Fig. 10 — 'Budded' proteinoid microsphere (×1300) [A, microsphere; and B, 'bud']

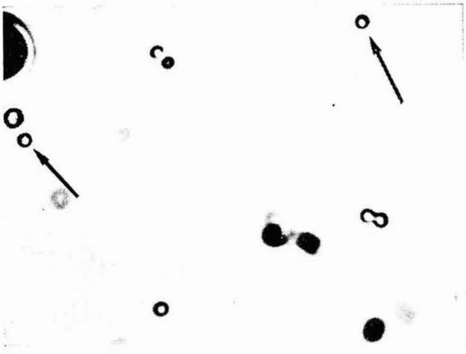


Fig. 11 — Separated 'buds' (×900)

first organisms must have been heterotrophs. One may find the arguments in the writings of Oparin[40], Haldane[54], Pirie[55], Pringle[56], Horowitz[57], Van Niel[58], and others. To repeat, the hypothetical need for nucleic acid-mediated constraints on primitive protein are seen not to apply because of the internal constraints on the primary structure of proteinoid[21].

Experiments in our laboratory have indicated how multiplication could occur also through the model of a primitive kind of binary fission[59] and growth by accretion, as well as through budding (Figs. 12 and 13).

With cyclical proliferation due to budding or fission, as depicted, Darwinian selection can, conceptually, occur. Increasingly incisive experiments on Darwinian selection from nonbiological precursors have in fact been performed with acid proteinoid and neutral proteinoid.

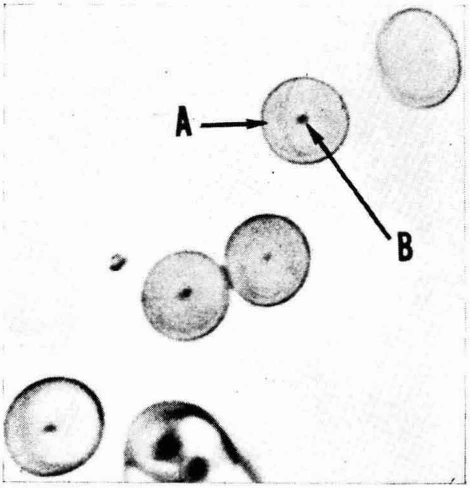


Fig. 12 — Accretion of proteinoid particle around crystal violet-stained 'buds' (×1100) [A, proteinoid particle; and B, stained centre]

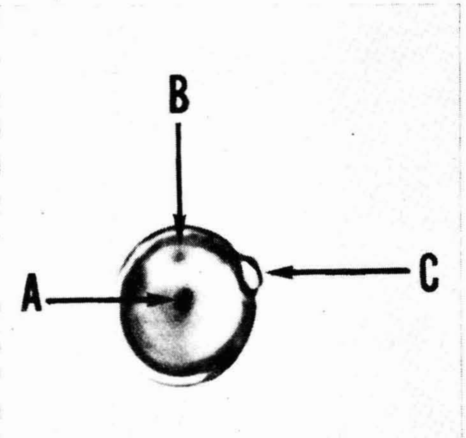


Fig. 13 — 'Daughter bud' on microsphere (×1500) [A, stained centre; B, microsphere by accretion; and C, 'daughter bud']

This paper along with other reports[7] explains briefly how a primitive organism capable of a kind of self-multiplication and possessing other salient properties could have emerged from primitive gases through the amino acids and subsequently through protein-like polymer. It is perhaps unnecessary to re-emphasize that this model of a kind of primitive unit is clearly not a contemporary cell, at least not of the usual contemporary organism. From this model, however, we visualize that in evolving to a contemporary organism a primitive self-replicating heterotroph would especially have had to develop an internal synthesis of protein and of polynucleotide.

The model processes which have been described are extremely simple. They consist of (i) heating above the boiling point of water, and (ii) the intrusion of water. This simple sequence requires (a) geologically anhydrizing temperatures, e.g. those above 100°, and (b) sporadic rain or other common geological events of water, such as drought or recession of the seas. Conditions (a) and (b) have been widespread geologically and, in fact, are quite widespread on the earth today. The reactions are rugged, their occurrence is not easily disturbed by added substances, since they are not solutes in aqueous solution, and the products have long-term stability. All details in the processes are found to be sequentially compatible.

To summarize, I use a 1966 quotation from Lederberg[42], "The point of faith is: make the polypeptide sequences at the right time and in the right amounts, and the organization will take care of itself. This is not far from suggesting that a cell will crystallize itself out of the soup when the right components are present." The results described here (and others) show that when amino acids are simply and suitably heated, polypeptide sequences, to at least some degree, organize themselves, and they do this in 'the right amounts'. The organization of the polypeptides does indeed take care of itself when water is added to thermal proteinoid, which appears to be the right component to crystallize out as a cell. Individual properties of proteins, polynucleotides, and of cells can be mimicked by other substances and units. Thermal proteinoid and its organized particles are the only chemically synthetic products, however, which have been shown to possess in *simultaneous* association and in life-like inclusiveness properties of the contemporary cell and its structural polymer, with indications of the potential for further evolution to contemporary cells.

Summary

Simple syntheses of polymers similar to those constituting contemporary cells have been demonstrated under thermodynamically feasible and geologically plausible conditions. Polyamino acids prepared by thermal condensation contain some proportion of each of the proteinogenous amino acids, the polymers have molecular weights of many thousands, and they possess other properties of

proteins. They are found to be limited in heterogeneity; the accumulated evidence suggests that internal forces impose much ordering of amino acid residues. A number of laboratories have reported catalytic, or 'protoenzymic' activities in these polymers for natural substrates.

Some progress in thermally polymerizing nucleotides has been recorded. Such polynucleotides, as well as RNA and DNA, are found to bind with polyamino acids when the latter contain sufficient proportions of basic amino acid. Although the limited heterogeneity of polyamino acids suggests that a code-related polynucleotide may have been unnecessary for the first cells, the experiments specify conditions under which the binding in a precursor of contemporary coding might have appeared prebiotically.

Simple treatment of thermal polyamino acids with water yields cell-like structures with many of the properties of contemporary living units. These properties include ability to accept stains, ultrastructure having a bileaflet boundary, protoenzymic activities, fissionability, selective retention of macromolecules, growth by accretion with participation in the reproduction of their own likeness, and a kind of motility.

The necessary geophysical conditions for the model of a spontaneous sequence converting primordial gases → amino acids → preprotein → protocells participating in the reproduction of their own likeness are: temperatures above the boiling point of water, and sporadic rain or other mechanisms of hydration. Such conditions are, of course, found on the contemporary earth, as well as being inferable for the primitive earth. The integrated interpretations constitute a relatively comprehensive theory of how primitive life appeared on earth.

References

1. *Self-assembly of structural subunits*, Symposium IV-4, Seventh International Congress of Biochemistry, Tokyo, Japan, 19-25 August 1967.
2. Ponnamperuma, C., *Sci. J., Lond.*, (May 1965), 39.
3. Fox, S. W., *Nature, Lond.*, **201** (1964), 336.
4. Ponnamperuma, C., cited in *The origins of prebiological systems and of their molecular matrices*, edited by S. W. Fox (Academic Press, New York), 1965, 221.
5. Oro, J., cited in *The origins of prebiological systems and of their molecular matrices*, edited by S. W. Fox (Academic Press, New York), 1965, 137.
6. Ferris, J. P. & Orgel, L. E., *J. Am. chem. Soc.*, **88** (1966), 3829.
7. Fox, S. W., *Nature, Lond.*, **205** (1965), 328.
8. Akabori, S., Okawa, K. & Saito, M., *Bull. chem. Soc. Japan*, **29** (1956), 608.
9. Matthews, C. N. & Moser, R. E., *Nature, Lond.*, **215** (1967), 1230.
10. Fox, S. W., cited in *Evolving genes and proteins*, edited by V. L. Bryson & H. J. Vogel (Academic Press, New York), 1965, 359.
11. Hayakawa, T., Windsor, C. R. & Fox, S. W., *Archs Biochem. Biophys.*, **118** (1967), 265.
12. Borsook, H. & Huffman, H. M., cited in *Chemistry of the amino acids and proteins*, edited by C. L. A. Schmidt (Charles C. Thomas, Springfield, Ill.), 1944, 822.
13. Dixon, M. & Webb, E. C., *Enzymes* (Academic Press, New York), 1957, 668.
14. Fox, S. W., *Am. Scient.*, **44** (1956), 347.
15. Steinman, G., *Archs Biochem. Biophys.*, **119** (1967), 76.
16. Fox, S. W. & Harada, K., *J. Am. chem. Soc.*, **82** (1960), 3745.
17. Vegotsky, A. & Fox, S. W., *Fedn Proc. Fedn Am. Socs exp. Biol.*, **18** (1959), 343.
18. Harada, K. & Fox, S. W., cited in *The origins of prebiological systems and of their molecular matrices*, edited by S. W. Fox (Academic Press, New York), 1965, 289.
19. Fox, S. W., Harada, K., Woods, K. R. & Windsor, C. R., *Archs Biochem. Biophys.*, **102** (1963), 439.
20. Fox, S. W. & Harada, K., *Fedn Proc. Fedn Am. Socs exp. Biol.*, **22** (1963), 479.
21. Fox, S. W. & Nakashima, T., *Biochim. biophys. Acta*, **140** (1967), 155.
22. Block, R. J. & Keller, S., *Contr. Boyce Thompson Inst.*, **20** (1960), 385.
23. Fox, S. W. & Wang, C. T., *Science, N.Y.*, **160** (1968), 547.
24. Calvin, M., *Am. Scient.*, **44** (1956), 248.
25. Fox, S. W., *Am. Nat.*, **87** (1953), 253.
26. Fox, S. W., Harada, K. & Rohlfing, D. L., cited in *Polyamino acids, polypeptides and proteins*, edited by M. Stahmann (University of Wisconsin Press, Madison), 1962, 47.
27. Noguchi, J. & Saito, T., cited in *Polyamino acids, polypeptides and proteins*, edited by M. Stahmann (University of Wisconsin Press, Madison), 1962, 313.
28. Usdin, V. R., Mitz, M. A. & Killos, J. P., *Archs Biochem. Biophys.*, **122** (1967), 258.
29. Rohlfing, D. L. & Fox, S. W., *Archs Biochem. Biophys.*, **118** (1967), 122.
30. Rohlfing, D. L. & Fox, S. W., *Archs Biochem. Biophys.*, **118** (1967), 127.
31. Fox, S. W. & Krampitz, G., *Nature, Lond.*, **203** (1964), 1362.
32. Fox, S. W., cited in *The origins of prebiological systems and of their molecular matrices*, edited by S. W. Fox (Academic Press, New York), 1965, 361.
33. Durant, D. & Fox, S. W., *Fedn Proc. Fedn Am. Socs exp. Biol.*, **25** (1966), 342.
34. Oshima, T., *Fedn Proc. Fedn Am. Socs exp. Biol.*, **26** (1967), 451.
35. Krampitz, G. & Hardebeck, H., *Naturwissenschaften*, **53** (1966), 81.
36. Rohlfing, D.L., *Archs Biochem. Biophys.*, **118** (1967), 468.
37. Krampitz, G., Diehl, S. & Nakashima, T., *Naturwissenschaften*, **54** (1967), 516.
38. Needham, A. E., *The uniqueness of biological materials* (Pergamon Press, Oxford), 1965.
39. Alcock, R. S., *Physiol. Rev.*, **16** (1936), 3.
40. Oparin, A. I., *The origin of life on the earth* (Oliver & Boyd, Edinburgh), 1957.
41. Wald, G., *Scient. Am.*, **191** (Aug. 1954), 44.
42. Lederberg, J., cited in *Current topics in developmental biology*, Vol. 1, edited by A. D. Moscona & A. Monroy (Academic Press, New York), 1966, 9.
43. Fox, S. W., McCauley, R. J. & Wood, A., *Comp. Biochem. Physiol.*, **20** (1967), 773.
44. Smith, A. E. & Bellware, F. T., *Science, N.Y.*, **152** (1966), 362.
45. Fox, S. W. & Yuyama, S., *Ann. N.Y. Acad. Sci.*, **108** (1963), 487.
46. Fox, S. W. & Yuyama, S., *J. Bact.*, **85** (1963), 279.
47. Murray, R. G. E., cited in *The bacteria*, Vol. I, edited by I. C. Gunsalus & R. Y. Stanier (Academic Press, New York), 1960, 55.
48. Wetlaufer, D. B., *Adv. Protein Chem.*, **17** (1962), 303.
49. Fox, S. W., McCauley, R. J., Fukushima, T., Windsor, C. R. & Montgomery, P. O'B., *Fedn Proc. Fedn Am. Socs exp. Biol.*, **26** (1967), 749.
50. Waehneldt, T. & Fox, S. W., *Biochim. biophys. Acta*, **134** (1967), 1.
51. Ponnamperuma, C., cited in *The origins of prebiological systems and of their molecular matrices*, edited by S. W. Fox (Academic Press, New York), 1965, 221.
52. Schwartz, A. W. & Fox, S. W., *Biochim. biophys. Acta*, **134** (1967), 9.
53. Calvin, M., *A.I.B.S. Bull.*, **12** (Oct. 1962), 29.
54. Haldane, J. B. S., *New Biol.*, **16** (1954), 12.
55. Pirie, N. W., *New Biol.*, **16** (1954), 41.
56. Pringle, J. W. S., *New Biol.*, **16** (1954), 54.
57. Horowitz, H. N., *Proc. natn. Acad. Sci., U.S.A.*, **31** (1945), 153.
58. Van Niel, C. B., cited in *The microbe's contribution to biology*, edited by A. J. Kluyver & C. B. Van Niel (Academic Press, New York), 1956, 155.
59. Fox, S. W. & Yuyama, S., *Comp. Biochem. Physiol.*, **11** (1964), 317.

The Photochemistry of Nucleic Acids

K. SIVARAMA SASTRY
Biochemistry Division, Department of Chemistry, Osmania University, Hyderabad 7

LIFE exists amidst radiation on which it is dependent in many ways. That radiation, in turn, modifies living cells has also been known for some time. But knowledge of the mechanisms involved in radiation effects, particularly at the molecular level, is not complete. During the past two decades, a great deal has been learnt regarding some of the gross changes brought about by ultraviolet light and, to a smaller extent, by visible light (in the presence of suitable photosensitizing dyes, in this case) in nucleic acids. The emphasis, in the present review, is on these aspects, with special reference to the molecular mechanisms involved. The review is not intended to be comprehensive. Rather, the salient features of the processes discussed are dealt with in the light of the more recent work in this expanding field. Earlier work, up to 1963, has been comprehensively reviewed by MacLaren and Shugar[1].

There are, in general, two distinctly different means whereby nucleic acids or their component purine and pyrimidine bases can be modified under the influence of light of suitable wavelength. One of these is based on the effects of ultraviolet light, which, so far as is known to date, primarily brings about alterations in the pyrimidine bases, uracil, cytosine and thymine. The modifications induced are either a hydration across the 5,6 double bond, or a dimerization of the pyrimidine rings of a pair of bases, resulting in the 5,6 carbons of one base residue being linked up with the 5,6 (or rarely 6,5 respectively) carbons of the second base residue to form a cyclobutane ring which now bridges the two participant pyrimidine ring systems. Such modifications result concomitantly in alterations in the ultraviolet absorbing properties of the bases and when the base residues in polynucleotides are involved, in loss or change in biological properties. Further, since some of these reactions sensitized by ultraviolet light are reversible under appropriate conditions, ultraviolet induced base modifications can be used to probe — at least tentatively, if not always unequivocally— into the contribution of base residues towards biological activity.

The second type of process is one that differs sharply from the above in that here visible light brings about a selective destruction of primarily guanine and derivatives of guanine (except for one special instance where adenine derivatives are attacked, as discussed later). But this visible light sensitized reaction(s), termed commonly as 'photodynamic inactivation', has two absolute requirements: (i) a photosensitizing dye, and (ii) oxygen. In the absence of either of these two, visible light does not affect purine bases. Whereas in ultraviolet sensitized reactions the energy transfer is directly from the incident radiation to the affected base residue, in photodynamic inactivation, the photosensitizing dye mediates the transfer of energy. The role of oxygen is obscure, but it may be associated with the production of certain intermediates, or products, e.g. the carbon dioxide formation from C-6 of guanine derivatives. Photodynamic inactivation results in destruction of the purine ring system and consequently is an irreversible phenomenon as well. As would be expected, therefore, in polynucleotides where functionally important guanine residues are photodynamically degraded, there is a unidirectional loss of function.

The present review deals with these two processes and summarizes some of the features of such photosensitized changes in bases as well as polynucleotides.

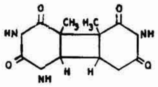
Photoproducts of Pyrimidines

The mode of inactivation of nucleic acids by ultraviolet light can be best understood by considering the changes brought about in the component bases, and several products have been identified and new ones are being reported. Till 1949, not much was known except that purines are far more resistant to ultraviolet light than the pyrimidines. The pyrimidine bases were generally believed to be irreversibly degraded. The discovery of Sinsheimer and Hastings[2], in 1949, that the loss of absorption brought about by ultraviolet irradiation of uracil, uridine and cytidylic acids was reversed by acidification to *p*H 1·0 was the first indication that pyrimidines could be reversibly modified. These workers further showed that the wavelength of ultraviolet light was important, for reversibility was possible only when the irradiation was performed at 2537 A. but not, for example, below 2100 A. The reversible photoproduct, now known to be one of the several formed, was postulated by Sinsheimer[3] to be the water addition product, 5-hydro-6-hydroxyuracil; its structure was established by Moore[4] by synthesis. This compound reverts to uracil almost completely on keeping for several hours at *p*H 1·0, or more rapidly by heating at this *p*H. Such heat and/or acid reversal, partial or complete, is now presumed (generally) to indicate a product of hydration across the 5,6 double bond.

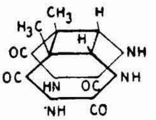
The next important milestone was the discovery of Beukers *et al.*[5] in 1959 that thymine, which also loses its ultraviolet absorption on irradiation at 2537 A. in frozen solution, could be reverted back to thymine not by acid or heat but by reirradiating the solution, after thawing. This was a second type of product derived from pyrimidines, and turned out to be a pyrimidine dimer. These two methods of obtaining reversal (acid and/or heat, on the one hand, and reirradiation, on the other) were extensively used in subsequent work as preliminary methods of probing into the structure of the photoproducts formed both with bases and with polynucleotides.

Since an understanding of the behaviour of thymine derivatives has been useful in understanding the behaviour of uracil derivatives, the photoproducts of thymine may be considered first.

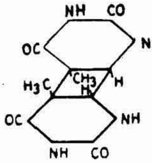
Thymine photoproducts — In solution, at 2537 A., thymine is photochemically altered more slowly than uracil[6]. On the other hand, in frozen solution, thymine undergoes conversion to a product with very low absorbance, very readily, and, as mentioned earlier, Beukers *et al.*[5] showed that this product reverts to thymine on reirradiation after thawing. It was unlikely that this was a water addition product, since it did not behave like uracil hydrate, and at the same time, the 5,6 double bond seemed to be involved as indicated by its absorption characteristics. Beukers and Berends[7] finally proved that the product was the dimer.



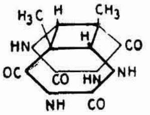
Wulff and Fraenkel[8] pointed out that there are, in fact, four possible types of dimers:



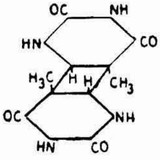
(meso-I)



(dl-II)



(dl-III)



(meso-IV)

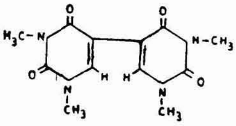
Compound I would be expected to be formed by intrachain dimerization of adjacent thymines in DNA. Compound II or IV (or a mixture of the two) would be possible if interchain dimers are formed[1,9-11] or crosslinks are formed in irradiated films of DNA[12-14]. Recently, the four possible dimers have been isolated on Dowex-1 columns[15].

Mixed dimers can be formed by irradiating mixtures of pyrimidines; a uracil-thymine dimer was shown to form in the frozen state[7,16].

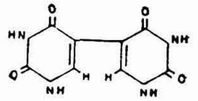
In aqueous solution, the quantum yields for dimer dissociation are far greater than for dimer formation[17,18]. Consequently, under solution irradiation conditions, the tendency is predominantly for the dimer to cleave back; in a frozen medium, such dissociation of dimer is prevented, since the dimer molecules are trapped in the ice matrix.

There is a wavelength dependence on thymine dimer production. For example, poly T is nearly quantitatively converted to dimers at 2800 A., whereas there is only 14 per cent conversion around 2400 A. (ref. 19).

Photoproducts of 5-*bromouracil* — It is well known that 5-bromouracil (BU) can get incorporated into DNA in place of thymine and that this is accompanied by increased ultraviolet sensitivity in bacteria[20] and bacteriophages[21]. Earlier observations showed that BU was photochemically inert in frozen solution[22,23]. The formation of some debrominated compounds, when irradiated under certain conditions in the presence of uracil, was suggested[24,25]. However, definite identification of the photoproducts has now been achieved[26]. These workers irradiated 5-bromouracil as also 5-bromo-1,3-dimethyluracil in aqueous solution with germicidal lamps. A mixture of several products was obtained among which were two coupled products: 5,5′-di-1,3-dimethyluracil (A) and 5,5′-diuracil (B).



A



B

The mechanism of formation suggested by Ishihara and Wang[26] involves dehalogenation, resulting in an intermediate free radical; two of such radicals combine to give the diuracil, for example. According to these workers a 5-hydroxy derivative is not formed as an intermediate.

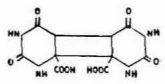
Photoproducts of uracil and its derivatives — The most important photoproduct formed by ultraviolet irradiation of uracil is, no doubt, the hydrate of uracil, 6-hydroxy-5-hydrouracil. Its reversion to uracil by acid or heat treatment has been mentioned[2-4]. Prusoff[27] reported the interesting finding that the hydrates of uracil and deoxyuridine are stable at room temperature as also at −70°C. and below, but revert readily to the parent compounds at −20°C.

Similar water addition products are formed by several derivatives of uracil. According to Sinsheimer[2], the photoproduct of uridine-2′-phosphate dehydrates more slowly than the corresponding derivative of the 3′-phosphate, but this has been contradicted recently[28]; the rate of reversal is reported to be in the order 2′, 5′, 3′; in all cases, however, the rate is less than for the nucleoside. Thus, the presence of phosphate stabilizes the hydrate, the extent of stabilization depending on the position of the phosphate.

The water addition product of 5-fluorouracil has been identified by Lozeron *et al.*[29]. 5-Fluorouracil does not seem to form a dimer.

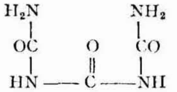
Uracil itself forms a dimer[30-32], but there appears to be some confusion about its stability. In general, it would seem that the dimer is, in any case, far less stable than the dimer of thymine. Its structure contains a cyclobutane ring system, by analogy, as in the thymine dimer. The dimer has been isolated from the products of irradiation in solution and the inhibition by oxygen of dimer formation studied recently by Greenstock *et al.*[33] who claim that hydration is not affected by oxygen. Mixtures of uracil and thymine form mixed dimers[7].

In solution, orotic acid, the 6-carboxy derivative of uracil, forms a dimer almost exclusively, in fact, more readily than in the case of adjacent uracil residues in polynucleotides, dimerization being favoured by light of 2700 A. (and higher wavelength). At lower wavelengths, an equilibrium exists between the dimer and the parent compound. This equilibrium is also shifted towards the monomer by oxygen[34]. This product and its formation have been studied recently[35,36]. The dimer has the structure[32]



Photoproducts of cytosine derivatives — Cytosine, in unbuffered solution, is decomposed by ultraviolet light somewhat like uracil, with attendant decrease in absorption, but much more slowly. The degree of reversibility is high for less than 25 per cent photolysis, but is practically nil when photolysis is around 80 per cent[37,38]. The nucleosides and nucleotides of cytosine, however, loose the absorption maximum at 2700 A., with simultaneous increase in absorbance at 2360 A. (ref. 6, 39). This process is completely reversible on acidification or heating, again, if irradiation is not very drastic. Thus, the photoproducts from the above derivatives of cytosine are more stable than those got from cytosine. By analogy with uracil, the products formed are assumed to be the water addition products. Generally, the isolation of photoproducts of cytosine has been very difficult due to their great instability compared to uracil hydrate. Besides, the actual nature of the products formed from cytosine and 1-methyl cytosine is not well understood. Though the hydrate may be formed initially, there is possibly a subsequent formation of irreversible products as indicated by the lack of reversion to parent compounds with extensive irradiation.

Photoproducts of purines — Very little is known about the photodecomposition of purines. Irradiation with ultraviolet light to the point of complete destruction of absorption spectrum results in the production of ammonia and urea[40]. Urea is apparently derived from the pyrimidine ring system of the purines. Virtually nothing can be said about the intermediates involved. From uric acid, crystalline triuret



$$\begin{array}{ccc} H_2N & & NH_2 \\ | & & | \\ OC & O & CO \\ | & \| & | \\ HN - & C & - NH \end{array}$$

was isolated and it was assumed that, in this case, allantoin was an intermediate, though this remains to be proved[41].

Photochemistry of Polynucleotides

The irradiation of biologically active polynucleotides results, under suitable conditions, in loss of function. The objectives of the enormous amount of effort currently being expended are to understand such changes at the molecular level. Several approaches have been tried in this context: isolation of photoproducts, where possible, and reversal by reirradiation or by other means, for example. These methods are based on the nature and properties of the photoproducts got from the nucleic acid bases. But the situation is complex, since alteration of function can conceivably result from very subtle changes, even in one single base; the molecular basis of such modifications is very difficult to detect directly. Nevertheless, a general picture is beginning to emerge.

Irradiation of DNA with very drastic doses of ultraviolet light leads to depolymerization as evidenced by fall in viscosity[42]. And, even with extensive irradiation resulting in an overall loss in the recovery of pyrimidines to the extent of about 30 per cent (after hydrolysis of the irradiated DNA), there is little change in adenine and guanine[43]. Thus, the pyrimidines would seem to be the major sites of the ultraviolet induced lesions.

Beukers *et al.*[44] were the first to isolate thymine dimers, TT*, from irradiated DNA, by conventional hydrolysis with perchloric acid. Soon after, Wacker *et al.*[16,45] (also Smith[22,46]) isolated TT from irradiated microorganisms; from *Esch. coli* as much as 9 per cent of the total thymine was isolated in this form. TT formation from adjacent thymines in individual strands is well authenticated and may account for up to 50 per cent of the biological inactivation caused by ultraviolet irradiation[47,48]. Though under ideal conditions, one could theoretically expect the damage to one thymine to result in inactivation, this does not seem to be realized in practice. Probably the nearest realized is in the phage ϕX174, where the number of TT per lethal hit is less than 1 (approximately 0·3) (ref. 49), but in this case, since the value is so much below 1, the participation of other bases cannot be completely excluded. With T-even phages, Haug and Sauberier[50] have concluded that the number of TT per lethal hit is not constant and that possibly cytosine is involved as well. Again, the ultraviolet sensitivities of bacteria with DNAs of different A-T contents are not directly related to the estimated T-T frequency, supporting the view that thymine dimers are not the sole lethal lesions[51].

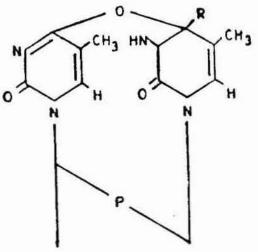
With the realization that TT formation cannot completely explain the effects of ultraviolet light, attempts are being made to look more critically at the whole process. Boyce and Howard-Flanders[52] and Riklis[53] reported an unidentified photoproduct in acid hydrolysates of DNA that behaves as UT (the uracil, in this case, could have resulted from the deamination of a cytosine residue[54]). Very recently, Setlow and Carrier[55] examined the question of heterodimers in irradiated DNA, and found that TT, CT and CC all occur. Acid hydrolysis results in the appearance of UT and UU dimers. Setlow and Carrier suggest rightly, that while speaking of photoproducts in DNA, the use of the term 'pyrimidine dimers' in place of TT is more appropriate and that the older data on the number of dimers formed, at a given dose, are subject to re-evaluation from this standpoint.

---

*The notation TT represents a thymine dimer. Similarly $U.H_2O$ represents uracil hydrate, with a water molecule added across the 5,6 double bond. The structures are discussed later.

Persuasive evidence, based on the chromatographic properties of the dimers TT and UT isolated from irradiated DNA, on Dowex-1 columns, that the dimers formed in both cases are of the 'meso-I' type (discussed under the section on 'Photoproducts of T') has been presented by Weinblum[56]. This would imply that the CT formed in DNA is from neighbouring residues in one strand of DNA.

However, this does not quite sum up the situation. There are doubtless several other types of products formed, whose nature is not well understood[52,53,57]. Varghese and Wang[58] recently reported one interesting product, which is not TT or CT, and shows an absorption maximum at 312 mμ. Apparently this product is formed in DNA both *in vitro* and *in vivo*. This new compound occurs usually along with TT, from which it is inseparable in most chromatographic systems, except *n*-butanol : acetic acid : water, 80:12:130. This serves to emphasize the dangers of relying on chromatographic separations as sole criteria for product characterization. A product termed T_pT[4] (abs. max. 325 mμ) is formed by irradiating T_pT (ref. 59) and this could conceivably be present in irradiated DNA as well, though it cannot be isolated from the latter, due to its instability to acid. This indicates the possibility of products that are hard to detect but can constitute additional lesions nevertheless. Yet another uncharacterized product, with an absorption maximum at 320 mμ, was reported by Smith[60].



R = H or OH

STRUCTURE OF $T_p T^4$

There is no doubt that TT formation, and in general, pyrimidine dimer formation, is, at least, one of the more important ultraviolet induced lesions in DNA. Cytosine hydrate is probably not involved to a major extent, because of its great instability. Besides, according to Setlow *et al.*[61], hydrate formation is generally suppressed in duplex structures. The question remains, finally, how pyrimidines in duplexes form dimers. The Watson-Crick structure does not appear to favour directly the formation of dimers with cyclobutane rings. Wang *et al.*[57] have put forth the interesting suggestion that the formation of dithymine peroxide (T-O-O-T) and a thymine coupled product (T-T) could be 'possible, but still undetected intermediates'[26,62,63]; such products at the intrastrand level are thought to be compatible with the Watson-Crick structure and even lead to the formation of TT.

Somewhat similar possibilities, namely dimer and/or hydrate formation, exist in ribopolynucleotides. In suitable ribopolynucleotides, both types of products have been detected, directly or indirectly. Studies with synthetic ribopolynucleotides have been fruitful in enabling the understanding of some of the intricate details of photoproduct formation and reversal[1]. The nature of the products formed in the poly (A+U) duplex has been studied by Wierzchowski and Shugar[64], who envisaged the initial formation of hydrates only, in this heteroduplex, in contrast to poly U alone. The nature of photolysis in this case has now been studied by a direct method, involving actual isolation of the photoproducts (from ^{32}P-labelled polymer), based on the observation that RNase digestion results in excision of products, such as $U.H_2O$, UU.U and $UU.U.H_2O$ (ref. 65). The last compound, a double photoproduct containing a uracil dimer adjacent to a uracil hydrate, is not cleaved, but can be isolated as the trinucleotide by this procedure. These workers have reported some interesting findings. Firstly, it would appear that both dimer and hydrate formation can happen as initial events. Secondly, the presence of dimer in the chain increases the probability of the adjacent uracil getting converted to a photoproduct. Even low exposures at 280 mμ result in the formation of dimer-rich sequences, such as UU UU U in both poly U and poly (A+U). These workers also found that the rate of formation of $U.H_2O$ is higher in poly U than in poly (A+U), indicating that a consequence of the more ordered structure in the latter polymer is a decreased yield of the hydrate. Such types of studies should be extended to other polynucleotides wherever possible and would doubtless be more fruitful.

Modification of biological activity in ribopolynucleotides occurs after exposure to ultraviolet light. For example, Grossman[66] first showed that irradiation of poly U reduces its ability to code for phenylalanine — as could be expected — and concomitantly enables it to code for serine. It would seem, therefore, that uracil hydrate (the dimer is a less likely candidate) formation results in the polymer being read as equivalent to UUC. Similarly, $C.H_2O$ in poly C seems to be the photoproduct involved in the decrease in GTP incorporation with a parallel stimulation of ATP incorporation, when irradiated poly C is used as template[67]. The photoinactivation of the much studied RNA from tobacco mosaic virus (TMV) is discussed under 'Photoreactivation'.

Reversal of Ultraviolet Damage

Since reirradiation at shorter wavelengths (around 2400 μ) would be expected to monomerize TT, such a procedure would supply information regarding the extent of damage caused by dimer formation. However, there are many other and better types of reversal known, among which may be cited 'dark repair' and 'photoreactivation'.

In bacteria, dark repair was detected by the finding that, in the first hour after irradiation, TT moved from the acid-insoluble fraction (cellular DNA) into the acid-soluble fraction. The organism apparently excises pyrimidine dimers[68,69]. What happens thereafter is not known precisely, but the recovery from damage that attends this phenomenon has led to the view that the gap left by excision is filled up by 'repair synthesis', the bases being put back normally, with the sequence of the strand opposite the excised region serving as the template. A mechanism for such patching up has been proposed[70]. This capacity for repair seems to be gene determined and in bacteria incapable of dark repair three genes, termed Uvr^{A}, Uvr^{B} and Uvr^{C}, have been mapped; these are widely dispersed on the genome[71]. Incidentally, as expected, such Uvr^{-} mutants show much less breakdown of DNA (dimer excision)[72]. Interestingly, the presence of bromouracil in DNA results in markedly enhanced breakdown of DNA, without attendant repair[73]. The suggestion has been made that the controlled switch from breakdown to synthesis (implied in the current concepts of dark repair) is modified by bromouracil, so as to favour instead further breakdown, resulting eventually in double strand breaks.

Bacteria vary in their ability to perform dark repair. Some are very resistant to ultraviolet damage as, for example, the strain B/r of *Esch. coli* and *Micrococcus radiodurans*[74]. Setlow and Duggan[75] showed that *M. radiodurans* has a very efficient repair mechanism.

Using mutant strains derived from *Esch. coli* WP2s, lacking in measurable ability to excise dimers[76] — and 20 times more sensitive than the parent WP2 which is resistant like B/r — Witkin studied some aspects of dark repair associated with mutation to prototrophy[77]. Witkin's results are very interesting, since they show that the dark repair involved in these strains is somewhat different from that associated with TT. Dark repair occurs, in this case, only if protein synthesis is immediately blocked after irradiation; this condition is not necessary for dark repair of TT. The particular mutations studied (all of which are of the suppressor variety) are supposed to arise primarily as a consequence of photoproducts "that can compete successfully with pyrimidine dimers only if protein synthesis after ultraviolet irradiation is inhibited"[77]. Thus, it would seem that dark repair can be associated not only with pyrimidine dimers but also with other lesions.

In contrast to dark repair, photoreactivation is dependent on reirradiation, usually with light of a longer wavelength in cellular systems. There is one instance where photoreactivation is brought about by radiation of wavelengths shorter than those producing inactivation — the unicellular algae, *Platymonas subcordiformis*[78]. Photoreactivation was discovered by Kelner in *Streptomyces griseus*[79,80] (the present status of the field of photoreactivation has been recently reviewed by Rupert[81]). But, it is Dulbecco's finding of photoreactivation in bacteriophages that has had important consequences from the point of view of the mechanisms involved[82]. The main difference between cells and the bacteriophage systems rests in the fact that the phages can be reactivated only after infection of the host. Also, the action spectrum, in the case of T2, with *Esch. coli* B/r as the host, is very similar to the action spectrum for the photoreactivation of the host cells[83]. Thus, phages use the host cell's recovery machinery as they do its biosynthetic capacity.

Transforming DNA, whose transforming ability is partly destroyed by ultraviolet irradiation can be reactivated *in vitro* by reirradiation with photoreactivating light in the presence of suitable cell extracts from *Esch. coli* B[84] or bakers' yeast[85], organisms that can themselves be photoreactivated, but not when mixed with extracts of *H. influenzae*, an organism that is nonphotoreactivable[86]. The cellular system has been studied in some detail[81]. The yeast cell system shows the expected behaviour characteristic of a typical enzyme. The yeast photoreactivating enzyme binds to irradiated DNA, but not to unirradiated DNA. Rupert has shown further that the enzyme does not bind to ultraviolet irradiated RNA[87]. Recently, the first demonstration of photoreactivation of a DNA virus (LPP-1) in an autotrophic microorganism, the alga *Plectonema boryanum*, has been made[88]. Here again, the wavelengths effective are longer ones (in the range 360-500 mμ). Light of wavelength greater than 570 mμ is not effective. Since red light promotes photosynthesis, it is evident that photosynthesis alone does not induce repair.

The yeast photoreactivating enzyme has now been purified about 3000-fold[89]. Using the yeast enzyme Cook[90] has shown directly that this enzyme splits dimers in irradiated DNA with a stoichiometric increase in monomeric thymine. The photoreactivating enzyme would appear capable of splitting pyrimidine dimers of all possible types, viz. TT, CT and CC, though not at identical rates.

In contrast to the single and double stranded DNA phages, which after ultraviolet inactivation can be photoreactivated with 'black light' (360 mμ), some RNA phages checked recently are not reactivated[91-93]. This is in contrast with a lot of plant viruses that are capable of photoreactivation[94]. TMV is rather unique, since the irradiated virus cannot be photoreactivated, but if TMV-RNA is treated with ultraviolet light, it can be photoreactivated in the tobacco plant cells[95,96]. The inactivation of TMV-RNA itself is somewhat wavelength-dependent[97], and the lesions involved are almost entirely of the hydrate type, and not dimers[98]. Up to 20 per cent substitution of uracil residues by 5-fluorouracil does not affect photoreactivability of TMV-RNA[99]. This would be expected if the hydrates of uracil and its analogue behave comparably from the standpoint of reversal. Further evidence that hydration constitutes the major lesion has been adduced for TMV-RNA; the inactivation proceeds faster in water than in D_2O[100].

It is of interest to note that the inactivation of the intact virus (TMV) is a somewhat different phenomenon. Here, the protein coat alters the nature of the response. A mild strain, designated U2, is roughly 6 times more sensitive than the common strain (U1), even though the infectious RNA from both strains is inactivated at not very different rates[101]. If cross-reconstitution of these viruses is made (using the RNA derived from one strain with the coat protein from the other), the hybrid viruses show the sensitivity characteristic of the parent virus, whose protein has been utilized for reconstitution[102]. The rate of inactivation of TMV-RNA is, therefore, directly related to the extent of shielding from ultraviolet light provided by the external protein. Further, the inactivating lesions, in the case of the intact virus, are at least partly associated with an ultraviolet mediated crosslinking of protein subunits to the RNA[103].

Photodynamic Inactivation

Ultraviolet irradiation of polynucleotides affects almost exclusively the pyrimidine base residues. In sharp contrast, photodynamic inactivation, viz. inactivation brought about by certain photosensitizing dyes in the presence of visible light, destroys only guanine residues. The only exception, so far reported, is the riboflavin sensitized destruction of adenine[104], where one of the products formed is hypoxanthine. The further breakdown of adenine beyond hypoxanthine is not known.

To understand photodynamic inactivation, it is necessary to study the mode of binding of sensitizing dyes to polynucleotides, as also the effect of light on the dye-polynucleotide complexes. At the present time, much more is known about the former aspect than about the latter. Since photodynamic inactivation sensitized by the two dyes, acridine orange and methylene blue, has been better studied, the following discussion centres to some extent round these two dyes.

From the standpoint of dye binding to polynucleotides, acridine orange offers some advantages over several other dyes. This dye has an absorption maximum at 492 mμ, with a small hump in the absorption curve at 460 mμ; the former peak is due to monomeric dye molecules and the hump at 460 mμ is the result of dye aggregation. At concentrations below $10^{-5}M$, the dye exists largely in the monomeric state. Also, acridine orange has considerable fluorescence ($\lambda_{\text{activation}} = 490$ mμ; $\lambda_{\text{fluorescence}} = 550$ mμ). Both absorption and fluorescence characteristics are altered when the dye binds to polynucleotides[105,106]. Depending on the relative concentrations of the dye and the polynucleotide, generally two types of complexes are known to be formed: complex I and complex II[107,108]. Complex I is produced at a polymer to dye ratio of 1:1 (expressed with respect to the phosphate content of the polymer), and complex II is obtained when the polymer is in 20-fold excess or more. The two types of complexes are distinguishable by their absorption and fluorescence characteristics. Complex I shows considerably reduced absorbance at 492 mμ and instead absorbs strongly around 460 mμ; concomitantly, the dye in this type of complex shows a strongly quenched fluorescence. In contrast, complex II has an absorption peak fairly close to 492 mμ — with various polynucleotides, the position of this peak is shifted to different extents — within 5-10 mμ. There is, at the same time, about 2-fold increase in fluorescence[108,109]. These optical characteristics of the two types of complexes are due to the fact that complex I represents a complete saturation of the polymer binding sites with acridine orange molecules, resulting — from the standpoint of dye molecule orientation — in a state analogous to that of highly aggregated dye molecules, the interaction between the ring systems of which results in loss of fluorescence; complex II is the other extreme where there is virtually no interaction between any two dye molecules bound to the polynucleotide. Under suitable conditions, the dye binds to both DNA and RNA in a very similar manner[110]. Lerman has shown that one of the modes of binding (particularly for complex II) is an 'intercalation' of dye molecules which get stacked between the nucleic acid bases[111]. Sivarama Sastry and Gordon[109] have found that in the presence of certain paramagnetic metal ions, with TMV-RNA, a third type of complex is formed wherein both the metal and the dye are bound to TMV-RNA, and has optical properties that distinguish it from the other complexes.

Biological inactivation can now be considered in the light of the above features of dye binding. Chessin's brief report of inactivation of TMV-RNA by high concentrations of acridine orange even in the dark (levels that would involve the formation of complex I) shows that complex I is inactive in itself[112]. Photodynamic inactivation is not involved here, and most probably the destruction of biological activity is rather a reflection of the inhibitory effect of high dye concentration *per se* on the infectivity of TMV-RNA. So, photodynamic inactivation of TMV-RNA is demonstrable only for complex II. The loss of infectivity of this complex shows a dependence upon the amount of illumination and follows first order kinetics[113]. Further, such biological inactivation is unattended by strand scission. The possible mechanism involved is discussed below. There are other instances of a similar nature, viz. the alteration of coding properties of poly UG photodynamically inactivated by methylene blue[114], and the somewhat unusual light dependent, iron sensitized destruction of infectivity of TMV-RNA[115]. Taken together, these studies show that photodynamic inactivation of the functional activity of polynucleotides need not involve a chain cleavage and that a modification of base (guanine) residues is adequate for the purpose.

It is of interest that the presence of paramagnetic metal ions in the ternary complex III protects TMV-RNA partially against photodynamic inactivation[113]. This is in line with another instance of metal ion protection of guanine derivative destruction photodynamically by lumichrome[116].

It is well established that the mechanism of photodynamic inactivation due to acridine orange[117] and methylene blue[118,119] is associated with a selective modification and/or destruction of guanine residues. Lumichrome also acts similarly by a specific destruction of guanine derivatives[120], and though not as well proved, it also presumably acts likewise towards guanine residues in polynucleotides. Thiopyronine attacks deoxyguanosine specifically[121]. An interesting feature of the action of these dyes on model guanine (or guanine-like) derivatives is that, under certain conditions, the breakdown products formed are quite different. Methylene blue produces 1,3-dimethyl-allantoin from theophyllin[119], lumichrome degrades guanine to give parabanic acid and guanidine[120], and both acridine orange[117] and methylene blue[118] yield ribosylurea, and small amounts of ribose as well as guanidine, when they act on guanosine in the presence of visible light. In all cases there are several other products formed as well in varying amounts.

Since none of the above dyes — the only ones studied in detail — affects any of the other bases, it follows that they are all essentially alike at least as regards their selectivity towards guanine residues in polynucleotides. However, the destruction of the guanine residues in itself does not explain one feature of photodynamic degradation of polynucleotides. As mentioned earlier, under mild conditions of dye concentration and illumination, the biological activity of polynucleotides is destroyed without strand scission[113,114]. On the other hand, if the conditions are more drastic with respect to dye as well as illumination, a severe depolymerization of polynucleotides is always observed[117,119,122,123]. Recent work on methylene blue sensitized destruction of guanosine[118] has shown that, under mild conditions, the cleavage of the N-C glycosidic bond may occur initially, and that beyond this stage, ribose also is destroyed. Though the actual intermediates involved are not known, these observations suggest that the former process is the one that is manifest in the phenomenon of biological inactivation without strand scission[124], and that the latter may be related to the observed depolymerization process.

Photodynamic inactivation of intact viruses shows slightly different features. Here too a destruction of the polynucleotide component may be a predominant mechanism, though photodynamic attack on amino acid residues in the protein coat cannot be altogether ruled out, since amino acids are destroyed by dyes[125] under suitable conditions. The latter possibility may, in certain cases, be a real one, though the extent to which this is a contributory factor is not known.

The dye-sensitized inactivation of certain viruses is sometimes hampered by an impermeability of the viral protein coat to the dye molecules, and can be partially bypassed by raising the *p*H[126]. TMV also shows this behaviour, though the enhancement of sensitivity by *p*H alteration from 7·0 to 9·2 is not as dramatic as with poliovirus[113,125]. In this respect TMV behaves like some enteroviruses[127]. Another interesting procedure which circumvents this inaccessibility of the nucleic acid to dyes has been described by Schaffer[128]. Schaffer could render poliovirus sensitive to photodynamic inactivation by including proflavin in the dye-host cell system, during the stage of virus synthesis. In this instance, the dye was incorporated into the virus, presumably within the particle. Acridine orange was likewise incorporated by VESV (vesicular exanthema of swine virus) and partially rendered sensitive[129]. But such dye incorporation into a virus is not known to be a general phenomenon. However, in cases where this is realized in practice, the sensitivity of the dye containing viruses, in contrast to the resistance of the viruses to externally added dye, indicates that the actual target of photodynamic inactivation is, at least primarily, the nucleic acid itself.

Implications and Prospects

The knowledge derived so far from the various investigations on the ultraviolet and photodynamic inactivation of nucleic acids and their component bases points to the need to understand the finer details of the mechanisms involved. It is evident that many gross features are already understood to some extent. But they raise further questions. In ultraviolet inactivation, doubtless, pyrimidine dimers and hydrates are the major types of lesions. However, many lines of evidence implicate as yet unknown types of base modifications that show unusual behaviour, particularly in various types of reactivation processes. These await clarification. The extent to which the modification of one base residue influences the susceptibility of neighbouring ones to inactivation is another important aspect, but this involves obtaining greater knowledge about base sequences in polynucleotides.

There are some practical advantages that may accrue when some of these aspects are understood in greater detail. The recent demonstration of a peculiar cleavage of pseudouracil by ultraviolet irradiation[130] may permit a specific method of cleaving molecules like sRNA, and this is already under study.

In a sense, ultraviolet and photodynamic inactivation are complementary methods of modifying polynucleotides. A beginning has just been made in understanding some features of the destruction of guanine moieties by photosensitizing dyes. If photodynamic inactivation can be suitably manipulated either by finding a suitable dye or by an appropriate choice of conditions, it is possible that a controlled degradation of polynucleotides adjacent to guanine locations can be achieved. Studies with methylene blue and acridine orange[113,123] have shown that the rate of guanine residue breakdown in model systems is very different from their destruction in polynucleotides. It is likely that the susceptibility of guanine residues in polynucleotides depends upon neighbouring base effects in the polymer.

Summary

The main features of the chemical modifications induced in nucleic acid bases as such and in the corresponding residues in polynucleotides brought about by ultraviolet light and photodynamic inactivation caused by visible light in the presence of suitable dyes are surveyed. Ultraviolet light affects primarily the pyrimidine bases, whereas photodynamic inactivation destroys mostly guanine. The changes brought about in both cases modify the biological activity of polynucleotides. The mechanisms involved in such base modifications, and the mode of reversal of damage in the case of ultraviolet-induced lesions have been discussed.

References

1. MacLaren, A. D. & Shugar, D., *Photochemistry of proteins and nucleic acids* (Pergamon Press Ltd, Oxford), 1964.
2. Sinsheimer, R. L. & Hastings, R., *Science, N.Y.*, **110** (1949), 525.
3. Sinsheimer, R. L., *Radiat. Res.*, **1** (1954), 505.
4. Moore, A. M., *Can. J. Chem.*, **36** (1958), 281.
5. Beukers, R., Ijlstra, J. & Berends, W., *Recl Trav. chim. Pays-Bas Belg.*, **78** (1959), 883.
6. Wierzchowski, K. L. & Shugar, D., *Biochim. biophys. Acta*, **25** (1957), 355.
7. Beukers, R. & Berends, W., *Biochim. biophys. Acta*, **41** (1960), 550.
8. Wulff, D. L. & Fraenkel, G., *Biochim. biophys. Acta*, **51** (1961), 332.

9. Marmur, J. & Grossman, L., *Proc. natn. Acad. Sci., U.S.A.*, **47** (1961), 778.
10. Marmur, J., Anderson, W. F., Matthews, L., Berns, K., Gajewska, E. E., Lane, D. & Doty, P., *J. cell. comp. Physiol.*, **58** (Suppl. 1) (1961), 33.
11. Grossman, L., Stollar, D. & Herrington, K., *J. Chim. Phys.*, **58** (1961), 1078.
12. Setlow, R. & Doyle, B., *Biochim. biophys. Acta*, **15** (1954), 117.
13. Baranowska, J. & Shugar, D., *Acta biochim. pol.*, **7** (1960), 505.
14. Shugar, D. & Baranowska, J., *Nature, Lond.*, **185** (1960), 33.
15. Weinblum, D. & Johns, H. E., *Biochim. biophys. Acta*, **114** (1966), 450.
16. Wacker, A., Dellweg, H. & Lodemann, E., *Angew. Chem.*, **73** (1961), 64.
17. Smietanowska, A. & Shugar, D., *Bull. Acad. pol. Sci. Cl. II, Ser. Sci. biol.*, 1961.
18. Setlow, J. K., *Radiat. Res.*, **14** (1961), 500.
19. Setlow, R. B. & Setlow, J. K., *Proc. natn. Acad. Sci., U.S.A.*, **48** (1962), 1250.
20. Greer, S., *J. gen. Microbiol.*, **22** (1960), 618.
21. Kaplan, H. S., Smith, K. C. & Tomlin, P. A., *Radiat. Res.*, **16** (1962), 98.
22. Smith, K. C., *Biochem. biophys. Res. Commun.*, **6** (1962), 458.
23. Wacker, A., Dellweg, H. & Weinblum, D., *J. molec. Biol.*, **3** (1961), 787.
24. Smith, K. C., in *Photophysiology*, Vol. II, edited by A. C. Giese (Academic Press Inc., New York), 1964, 344-9.
25. Wolf, W. & Kharasch, N., *J. org. Chem.*, **26** (1961), 283.
26. Ishihara, H. & Wang, S. Y., *Nature, Lond.*, **210** (1966), 1222.
27. Prusoff, W. H., *Biochim. biophys. Acta*, **68** (1963), 302.
28. Logan, D. M. & Whitmore, G. F., *Photochem. Photobiol.*, **5** (1967), 143.
29. Lozeron, H., Gordon, M. P., Gabriel, T., Tautz, W. & Duschinsky, R., *Biochemistry*, **3** (1964), 1844.
30. Beukers, R. & Berends, W., *Biochim. biophys. Acta*, **38** (1960), 573.
31. Wacker, A., Weinblum, D., Träger, L. & Moustafa, Z. H., *J. molec. Biol.*, **3** (1961), 790.
32. Smith, K. C., in *Photophysiology*, Vol. II, edited by A. C. Giese (Academic Press Inc., New York), 1964.
33. Greenstock, C. L., Brown, I. H., Hunt, J. W. & Johns, H. E., *Biochem. biophys. Res. Commun.*, **27** (1967), 431.
34. Sztumpf, E. & Shugar, D., *Photochem. Photobiol.*, **4** (1965), 719.
35. Sztumpf-Kulikowska, E., Shugar, D. & Boag, J. W., *Photochem. Photobiol.*, **6** (1967), 41.
36. Beukers, R. & Berends, W., *Biochim. biophys. Acta*, **49** (1961), 181.
37. Shugar, D. & Wierzchowski, K. L., *Biochim. biophys. Acta*, **23** (1957), 657.
38. Wierzchowski, K. L. & Shugar, D., *Acta biochim. pol.*, **8** (1961), 219.
39. Sinsheimer, R. L., *Radiat. Res.*, **6** (1957), 121.
40. Canzanelli, A., Guild, R. & Rapport, D., *Am. J. Physiol.*, **167** (1951), 364.
41. Fellig, J., *Science, N.Y.*, **119** (1954), 129.
42. Hollaender, A., Greenstein, J. P. & Jenrette, W. W., *J. natn. Cancer Inst.*, **2** (1941), 23.
43. Errera, M., *Biochim. biophys. Acta*, **8** (1952), 115.
44. Beukers, R., Ijlstra, J. & Berends, W., *Recl Trav. chim. Pays-Bas Belg.*, **79** (1960), 101.
45. Wacker, A., Dellweg, H. & Weinblum, D., *Naturwissenschaften*, **47** (1960), 477.
46. Smith, K. C., *Biochem. biophys. Res. Commun.*, **8** (1962), 157.
47. Wulff, D. L. & Rupert, C. S., *Biochem. biophys. Res. Commun.*, **7** (1962), 237.
48. Setlow, J. K. & Setlow, R. B., *Nature, Lond.*, **197** (1963), 560.
49. David, C. N., *Z. VererbLehre*, **94** (1964), 318.
50. Haug, A. & Sauberier, W., *Photochem. Photobiol.*, **4** (1965), 555.
51. Haynes, R. H., in *Physical processes in radiation biology*, edited by L. Augenstein, R. Mason & B. Rosenberg (Academic Press Inc., New York), 1964, 51.
52. Boyce, R. P. & Howard-Flanders, P., *Proc. natn. Acad. Sci., U.S.A.*, **51** (1964), 293.
53. Riklis, E., *Can. J. Biochem.*, **43** (1965), 1207.
54. Dellweg, H. & Wacker, A., *Z. Naturf.*, **17b** (1962), 827.
55. Setlow, R. B. & Carrier, W. L., *J. molec. Biol.*, **17** (1966), 237.
56. Weinblum, D., *Biochem. biophys. Res. Commun.*, **27** (1967), 384.
57. Wang, S. Y., Patrick, M. H., Varghese, A. J. & Rupert, C. S., *Proc. natn. Acad. Sci., U.S.A.*, **57** (1967), 465.
58. Varghese, A. J. & Wang, S. Y., *Science, N.Y.*, **156** (1967), 957.
59. Pearson, M. L., Ottemmeyer, R. P. & Johns, H. E., *Photochem. Photobiol.*, **4** (1965), 739.
60. Smith, K. C., *Photochem. Photobiol.*, **2** (1963), 508.
61. Setlow, R. B., Carrier, W. L. & Bollum, F. J., *Proc. natn. Acad. Sci., U.S.A.*, **53** (1965), 1111.
62. Alcantara, R. & Wang, S. Y., *Photochem. Photobiol.*, **4** (1965), 473.
63. Wang, S. Y. & Alcantara, R., *Photochem. Photobiol.*, **4** (1965), 477.
64. Wierzchowski, K. L. & Shugar, D., *Photochem. Photobiol.*, **1** (1962), 21.
65. Pearson, M. & Johns, H. E., *J. molec. Biol.*, **20** (1966), 215.
66. Grossman, L., *Proc. natn. Acad. Sci., U.S.A.*, **48** (1962), 1609.
67. Ono, J., Wilson, R. & Grossman, L., *J. molec. Biol.*, **11** (1965), 600.
68. Setlow, R. B. & Carrier, W. L., *Proc. natn. Acad. Sci., U.S.A.*, **51** (1964), 226.
69. Boyce, R. P. & Howard-Flanders, P., *Proc. natn. Acad. Sci., U.S.A.*, **51** (1964), 297.
70. Pettijohn, D. & Hanawalt, P., *J. molec. Biol.*, **9** (1964), 395.
71. Boyce, R. P., *Nature, Lond.*, **209** (1966), 688.
72. Boyce, R. P. & Howard-Flanders, P., *Z. VererbLehre*, **95** (1964), 345.
73. Aoki, S., Boyce, R. P. & Howard-Flanders, P., *Nature, Lond.*, **209** (1966), 686.
74. Duggan, D. E., Anderson, A. W., Elliker, P. R. & Cain, R. F., *Fd Res.*, **24** (1959), 376.
75. Setlow, J. K. & Duggan, D. E., *Biochim. biophys. Acta*, **87** (1964), 664.
76. Hill, R. F., *Photochem. Photobiol.*, **4** (1965), 563.
77. Witkin, E. W., *Science, N.Y.*, **152** (1965), 1345.
78. Halldal, P., *Physiologia Pl.*, **14** (1961), 890.
79. Kelner, A., *J. Bact.*, **56** (1948), 157.
80. Kelner, A., *J. Bact.*, **57** (1948), 73.
81. Rupert, C. S., in *Photophysiology*, Vol. II, edited by A. C. Giese (Academic Press Inc., New York), 1964, 283.
82. Dulbecco, R., *Nature, Lond.*, **163** (1949), 949.
83. Jagger, J. & Latarjet, R., *Annls Inst. Pasteur, Paris*, **91** (1956), 858.
84. Rupert, C. S., Goodgal, S. H. & Herriott, R. M., *J. gen. Physiol.*, **41** (1958), 451.
85. Rupert, C. S., *J. gen. Physiol.*, **43** (1960), 573.
86. Goodgal, S. H., Rupert, C. S. & Herriott, R. M., in *The chemical basis of heredity*, edited by W. D. McElroy & B. Glass (Johns Hopkins Press), 1957, 341.
87. Rupert, C. S., in *Photophysiology*, Vol. II, edited by A. C. Giese (Academic Press Inc., New York), 1964, 287.
88. Wu, J. H., Lewin, R. A. & Werbin, H., *Virology*, **31** (1967), 657.
89. Muhammed, A., *J. biol. Chem.*, **241** (1966), 516.
90. Cook, J. S., *Photochem. Photobiol.*, **6** (1967), 97.
91. Winkler, U., *Photochem. Photobiol.*, **3** (1964), 37.
92. Rauth, A. M., *Biophys. J.*, **5** (1965), 257.
93. Zinder, N. D., *A. Rev. Microbiol.*, **5** (1965), 455.
94. Bawden, F. C., *Plant viruses and virus diseases* (Ronald Press Co., New York), 1964.
95. Bawden, F. C. & Kleczkowski, A., *Nature, Lond.*, **183** (1959), 503.
96. Rushizky, G. W., Knight, C. A. & MacLaren, A. D., *Virology*, **12** (1960), 32.

97. Merriam, V. & Gordon, M. P., *Proc. natn. Acad. Sci., U.S.A.*, **54** (1965), 1261.
98. Merriam, V. & Gordon, M. P., *Photochem. Photobiol.*, **3** (1967), 709.
99. Lozeron, H. A. & Gordon, M. P., *Biochemistry*, **3** (1964), 507.
100. Tao, M., Gordon, M. P. & Nester, E. W., *Biochemistry*, **5** (1967), 4146.
101. Siegel, A., Wildman, S. G. & Ginoza, W., *Nature, Lond.*, **178** (1956), 1117.
102. Streeter, D. G. & Gordon, M. P., *Photochem. Photobiol.*, **6** (1967), 413.
103. Goddard, J., Streeter, D. G., Weber, C. & Gordon, M. P., *Photochem. Photobiol.*, **5** (1966), 213.
104. Uehara, K., Mizoguchi, T. & Hosami, S., *J. Biochem., Tokyo*, **59** (1966), 550.
105. Bradley, D. F., *Trans. N.Y. Acad. Sci.*, **24** (1961), 64.
106. Bradley, D. F. & Felsenfeld, G., *Nature, Lond.*, **184** (1959), 1920.
107. Steiner, R. F. & Beers, R. F., in *Polynucleotides* (Elsevier Publishing Co., Amsterdam), 1961.
108. Steiner, R. F. & Beers, R. F., *Archs Biochem. Biophys.*, **81** (1959), 75.
109. Sivarama Sastry, K. & Gordon, M. P., *Biochim. biophys. Acta*, **91** (1964), 406.
110. Ronadive, N. S. & Korgaonkar, K. S., *Biochim. biophys. Acta*, **39** (1960), 547.
111. Lerman, I. S., *J. molec. Biol.*, **3** (1961), 18.
112. Chessin, M., *Science, N.Y.*, **132** (1960), 1840.
113. Sivarama Sastry, K. & Gordon, M. P., *Biochim. biophys. Acta*, **129** (1966), 32.
114. Simon, M. I., Grossman, L. & Van Vunakis, H., *J. molec. Biol.*, **12** (1965), 50.
115. Singer, B. & Fraenkel-Conrat, H., *Biochemistry*, **5** (1966), 2446.
116. Sussenbach, J. S. & Berends, W., *Biochem. biophys. Acta*, **76** (1963), 154.
117. Sivarama Sastry, K. & Gordon, M. P., *Biochim. biophys. Acta*, **129** (1966), 42.
118. Waskell, L. A., Sivarama Sastry, K. & Gordon, M. P., *Biochim. biophys. Acta*, **129** (1966), 49.
119. Simon, M. I. & Van Vunakis, H., *J. molec. Biol.*, **4** (1962), 488.
120. Sussenbach, J. S. & Berends, W., *Biochim. biophys. Acta*, **95** (1965), 184.
121. Wacker, A., Turck, G. & Gerstenberger, A., *Naturwissenschaften*, **50** (1963), 377.
122. Friefelder, D., Davidson, P. F. & Geiduschek, F. P., *Biophys. J.*, **1** (1961), 389.
123. Simon, M. I. & Van Vunakis, H., *Archs Biochem. Biophys.*, **105** (1964), 197.
124. Singer, B. & Fraenkel-Conrat, H., *Biochemistry*, **5** (1966), 2447.
125. Sluyterman, L. A., *Biochim. biophys. Acta*, **60** (1962), 557.
126. Wallis, C. & Melnick, J. L., *J. Bact.*, **89** (1965), 41.
127. Hiatt, C. W., *Trans. N.Y. Acad. Sci.*, **23** (1960), 66.
128. Schaffer, F. L., *Virology*, **18** (1962), 412.
129. Hackett, A. J., *Photochem. Photobiol.*, **1** (1962), 147.
130. Tomasz, M. & Chambers, R. W., *J. Am. chem. Soc.*, **86** (1964), 4216.

The Pittsburgh Conference

The Twentieth Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy will be held at Cleveland, Ohio, USA, during 2-7 March 1969. Symposia will be held on: (i) Analytical techniques on the horizon; (ii) Emission spectroscopy; (iii) Computer interfacing with analysis; (iv) Spectroscopic analysis of glasses and oxides; (v) Spark source mass spectroscopy; (vi) Analysis — Food and agricultural chemicals; (vii) Infrared spectroscopy; (viii) Specific ion electrodes; and (ix) Nuclear magnetic resonance in solids.

Authors wishing to present papers at the conference should submit three copies of a 150-word abstract to William M. Hickam, Westinghouse Research Laboratories, Pittsburgh, Pennsylvania 15235, USA, before 15 October 1968. Further details can be obtained from G. L. Carlson, Chairman, Pittsburgh Conference, Carnegie-Mellon University, Mellon Institute, Pittsburgh, Pa 15213, USA.

REVIEWS

SCIENTIFIC EXPERIMENTS FOR MANNED ORBITAL FLIGHT: Vol. 4, edited by Peter C. Badgley (American Astronomical Society, Washington DC), 1965. Pp. xiv+358

A number of accounts are available of the scientific experiments conducted in unmanned and purely scientific satellites. A detailed account of the scientific experiments for manned orbital flights is, however, brought out for the first time by the American Astronomical Society. This excellent book which forms the proceedings of the 'Third Goddard Memorial Symposium on Scientific Experiments for Manned Orbital Flight', held during 18-19 March 1965 at Washington DC, contains eighteen chapters by various experts and is edited by P. C. Badgley of NASA, USA.

The different chapters encompass a wide variety of subjects from geodesy and meteorology to biophysics and geochemistry and their applications to agriculture, navigation and weather forecasting. Even though many of the experiments can and are performed in unmanned scientific satellites, a manned platform has the advantage of allowing a large weight and power capability, thereby making it feasible to fly a number of experiments at the same time. Furthermore, the presence of a trained human specialist introduces great simplifications in the design of the equipment by eliminating the need for many items which would have to be included in an unmanned experiment. As Prof. Singer points out: "Man is the lowest cost 150 pound nonlinear all-purpose computing system which can be mass-produced by unskilled labour!"

The articles by Lowman and Chang, Garrison *et al.* and Gillis and Leestma deal mainly with hyper-altitude photography and its applications to geologic reconnaissance, hydrology, forestry and geography. These applications are especially important in the case of mountainous terrains and oceanic surfaces having poor cartographic coverage. The application of the knowledge derived from the synoptic view of the earth to the understanding of the nature and extent of ice conditions and its application to navigation as well as to the evaluation of man's effects upon his environment are described. The application of imaging and altimeter-type radars described by Pierson *et al.* will provide an additional technique for geodesic applications.

The nocturnal photographs of clouds as well as other data such as terrain thermal features and ice distribution have been obtained using high resolution infrared radiometer (HRIR), a technique which has already been extensively used in Nimbus and Tiros satellites. The application of both visual and infrared photography to meteorology is very well described by Gawarecki *et al.* and Emery. Operationally, these observations are useful in the issue of cyclone and storm warnings, for aircraft flight briefings and in aiding navigation of ships.

A good planning of agriculture requires an increase in the gathering and flow of accurate information which will enable us to determine the type of crops that should be planted, the detection and planning of remedial measures to achieve erosion control, weed control, fencing, soil amendment, etc. The aerial surveys are, therefore, very important to increase the agricultural output of the world as a whole. The article by Colwell and Shay describes the various applications of remote sensing in agriculture and forestry in a very lucid way.

Another important application of space research, namely the use of satellites in the field of communications, is described by Ehrlich. Since the orbiting of Score and Echo-I satellite in 1958, a number of improved satellites such as Syncom, and ATS (application satellites) have been launched to provide improved communication. A brief description of these satellite systems is given in this chapter.

The study of basic physical and biophysical phenomena under Zero-G conditions and the possibility of understanding the biomedical and human factors for the success of future manned space missions are also described very well. On the whole, the book contains a large amount of valuable information, hitherto not available to the scientific community at large. Besides its general interest to public at large, the book will also be very useful to the specialist who is not directly involved in the space programme.

U. R. RAO

SOURCE BOOK ON ATOMIC ENERGY by Samuel Glasstone (D. Van Nostrand Co. Inc., London), 1967. Pp. vii+883. Price $ 9.25

The *Source Book on Atomic Energy*, first published in 1950, revised again in 1958, has been very popular with students of nuclear science and engineering. The appearance of the third edition after a lapse of nearly a decade has been quite timely, especially in view of the tremendous advances made on several fronts of nuclear energy and its applications.

The text now runs to 856 pages, nearly 240 pages more than in the second edition. A section by section comparison of the second and third editions will bring home the thoroughness and extensive nature of the revision. There are now twenty chapters rearranged in a more logical manner and some of the titles are modified. Each chapter is divided into several main sections and in the light of recent developments, they have been expanded in considerable detail. For example, in the chapter on 'Fundamentals of electricity and matter', the sections on matter and anti-matter, muons and mesons have been enlarged. The chapter on the 'Structure of the atom' includes more details on nuclear magnetic and electron spin resonance and their applications in the study of molecular structure. In the chapter on the 'Detection and measurement of nuclear radiations' new sections are devoted to semiconductor detectors, spark chambers and scintillation-counter hodoscope. The section on Mössbauer effect and its applications is a totally new section in the chapter on 'Nuclear radiations'.

The chapter on the 'Uses of isotopes and radiations' contains detailed accounts of new applications in agriculture, cellular biology, crime detection, isotopic dating, industry, medicine and radiography. The sections on the diagnostic and therapeutic applications of radioisotopes in medicine have received considerable revision. Sections on the whole-body counters, radioisotope scanners and scintillation cameras which have revolutionized the tracer techniques in biological systems are again totally new additions. The sections on the application of radiations in sterilization and food preservation, in making nuclear batteries, and in radiation chemistry are also new additions. Separate chapters are devoted for 'Cosmic rays' and 'Elementary particles', both of which have received considerable elaboration.

A refreshing feature of the new edition is that the text is interspersed with photographs of some eminent scientists. The list of references including surveys of historical importance, semi-popular articles, reviews and texts of a specialized nature will be found to be very useful to the readers. The non-mathematical treatment permits most of the lay readers to get a fair knowledge of complex subjects like reactor engineering and technology. The expert arrangement of the topics and the clear diction make the book unique in the realm of science writing. This is one of the few books wherein information can be found on the extensive peaceful uses of atomic energy. The revised and enlarged *Source Book on Atomic Energy* will no doubt be found as a very useful reference text for laymen, students of science and engineering, teachers and scientists.

V. K. IYA

THE IDENTIFICATION OF VAT DYES ON CELLULOSIC MATERIALS by D. A. Derrett-Smith & J. Gray (Pergamon Press Ltd, Oxford), 1967. Pp. v+113. Price 35*s*.

It is difficult to see the purpose of publishing this book which provides very little information additional to the tables in *J. Soc. Dyers Col.* compiled by Derrett-Smith *et al.* in 1940, 1947 and 1956. There are a few minor changes to conform to changes in the pattern cards of dye manufacturers; but the claim that the book has been 'brought up to date' is not justified. The dyes of only four British, three West German and four Swiss manufacturers are considered; other European countries, the Soviet Union, Japan, India and America are ignored. Every dye manufacturer and user possesses or has access to the *Colour Index* and its supplements, a look at which shows the inadequacy of this book. Literature references are very casual and arbitrary. Except for Derrett-Smith's own papers all the references in the introduction are to 1937 and earlier publications. Even Herzog's *Reactionstabelle der Kupenfarbstoffe*, on which Derrett-Smith's original work was based, is the 1933 and not the 1941 edition.

On the basis of five simple tests and seven tables a rough and ready method is provided for identifying vat dyes of eleven manufacturers. The tables cannot be used for mixtures of vat dyes, because chromatographic and other methods of separation are not discussed. The tables are also valueless for dealing with cellulose-polyester fibre mixtures.

Spectroscopic methods are not mentioned, and in general the book makes no attempt to use the knowledge that has become available during the last twenty years. The value of the tests would have been greatly increased by an attempt at relating the colour reactions to the chemical constitution of the dyes [contrast W. Bradley, *JSDC*, **56** (1940), 296, *et sequa*].

One wonders for whom the book is intended when statements so banal as the following are made: "The sulphuric acid must be kept in a bottle with a well-fitting glass stopper, as otherwise it readily absorbs moisture."

Chapter IV contains a superficial treatment, which again takes no account of recent literature, of the "identification of the classes of dyes commonly found on cellulosic materials'. Referring to mixtures of vat dyes, it is stated that "where the components of a mixture shade have not been well chosen, it is frequently possible to obtain evidence as to the identity of each component", but surely it is more reasonable to expect that a dye manufacturer or a dyer will not mix dyes with 'wide difference in vatting or in exhaustion properties'.

Chapter V attempts to identify halogenated indanthrones, but the tests and tables are of little use in the light of the fact that in *Colour Index* (Vol. III, p. 3535), which also cites a paper in *Proc. Ind. Acad. Sci.*, **28A** (1948), 236, the chlorinated indanthrones have been classified as simply as possible, but mixtures of derivatives differing in degree of chlorination appear as commercial dyes and complicate classification based on chemical constitution.

K.V.

GRUNDLAGEN DER SYNTHESE VON ZWISCHENPRODUKTEN UND FARBSTOFFEN by N. N. Woroshzow; translated by E. Baumann & F. Bahr (Akademie-Verlag G.m.b.H., Berlin), 1966. Pp. 1059

Academician Woroshzow is in an excellent position to write a book on the principles underlying the synthesis of intermediates and dyes in view of his background as an organic chemist and his intimate connection with research on dyes in the Soviet Union. His book of the same title (4th edition) published in Russian in 1955 was a classic at that time and proved to be most valuable for study and reference by organic chemists concerned with dyes. The German translation, which was published in 1966 but became generally available only in 1967, is, however, somewhat disappointing for three reasons. (1) It is largely a translation of the 1955 edition. Although literature references are brought up to 1962 (and a few to 1963 and 1964), their contents are not discussed in the body of the book. For instance, the benzidine rearrangement, on which extensive work has been carried out during the last ten years, is discussed only in terms of literature preceding 1954. There is no reference to Zollinger's English version of 1961, entitled Azo and Diazo Chemistry, which is a considerable advance on the German edition of 1958. (2) Many reactions are discussed which are irrelevant to dyes and intermediates. (3) The statement in the introduction that the production of intermediates from the raw materials is more difficult than the production of dyes may be true from the chemical engineering and technology points of view, but not in relation to the reactions and their mechanisms. It is, therefore, a pity that, as stated categorically by the author in the introduction, the synthesis of dyes is only touched upon. Aromatic substitution and other reactions for making dye intermediates are largely covered in books on organic or physical organic chemistry, but text-books of organic chemistry include only short chapters on dyes, mainly of a descriptive character. Pryor's book on the mechanisms of sulphur reactions makes no reference to dyes, and the part played by sulphur in the synthesis of dyes is one example of a topic which needs to be discussed as thoroughly as the present stage of our knowledge allows. Reactive dyes, which obviously represent the most important development in synthetic dyes after the Russian edition was published, find a place only in two footnotes in the German edition. Apart from their technical importance, the reactive dyes and their application to cellulose involve many interesting reactions which are being actively investigated by synthetic organic chemists in the dyestuff industry and by physical chemists. Another neglected area in which important advances have been made in recent years is the constitution of metal-dye complexes. The reviewer feels that the omission of double bonds in aromatic ring systems in his book on dyes was a serious error, although the convention was explained in the prefatory notes. This error is repeated in the present book.

Subject to the above reservations, the book is a valuable and scholarly contribution to the literature of organic reactions with special reference to dye intermediates. A particularly useful feature is the coverage of the work of Russian authors such as Woroshzow himself, Poray-Koshitz, Stepanov and Dokhunikhin which has not received adequate attention in European and American books. Fifteen chapters deal in great detail with the theoretical and practical aspects of sulphonation, nitration, halogenation, amination, diazotization and coupling, alkylation, acylation, oxidation, thionation, reduction, condensation and rearrangements.

K.V.

CHEMISTRY IN THE UTILIZATION OF WOOD by R. H. Farmer (Pergamon Press Ltd, Oxford), 1967. Pp. viii+193. Price 35*s*.

In 193 pages of small size, clearly printed, Dr Farmer of the Forest Products Research Laboratory in England has given a remarkably comprehensive account of the utilization of wood and its dependence on the chemical constituents. The purpose of the author, which is to provide students of wood technology and technicians in the wood-using industries with a knowledge of the fundamental properties of wood which influence its utilization as constructional material and as raw material for paper, rayon, and other cellulose derivatives, has been amply fulfilled. At the end of each chapter there is a short bibliography, but this is one feature in which there is room for improvement. Too many of the references are to books and articles which have become out of date in an area in which many developments have taken place in recent years. For instance, the bibliography for the chapter on 'Destructive distillation of wood' mentions Bunbury's book of 1927 and an article in Thorpe's dictionary. References to the original papers of Sandermann, Rudman and others would have helped the reader to go deeper into some of the topics in which his interest must have been excited by the brief but interesting and stimulating account given by Dr Farmer. Limitations of space have compelled him to devote only a page to polymer-impregnated wood, and many readers would undoubtedly wish to study this subject more thoroughly and perhaps undertake programmes of research.

Twelve chapters deal respectively with chemical composition, chemistry of wood components, wood analysis, influence of extractives on the properties and utilization of wood, use of timber in conjunction with chemicals, conversion of wood into chemical products (sugars and other products of hydrolysis, hydrogenation products, fertilizers and composts), corrosion of metals in association with wood, wood-water relationships, chemical aspects of attack by fungi and insects, pulp and paper manufacture, board materials, and wood distillation. In addition to an index there is a list of common and botanical names of important timbers.

This reviewer has had occasion to remark in connection with reviews of similar books that much less attention to research on our forest resources is being paid in our country, both in relation to other countries and our own record in the past. The Forest Research Institute at Dehra Dun is receiving far less financial and moral support than it deserves. It is perhaps too much to hope that those in authority in the Centre and the States and who are concerned with our forests will find the time to read this small book.

K.V.

PERFUMERY AND FLAVOURING SYNTHETICS by Paul Z. Bedoukian (Elsevier Publishing Co., Amsterdam), 1967. Pp. xvii+395

This book is an extended and modified version, and not truly a second edition, of the earlier book entitled *Perfumery Synthetics and Isolates* by the same author. Dr Bedoukian is an authority on the subject and, like his earlier book, the present volume is bound to prove a success. It deals with an area of chemistry in which there is a lack of comprehensive books. The book covers almost all the well-known and important items of perfumery chemicals which are used in the industry. These have been arranged in the alphabetical order of functional groups. Each item is covered by a brief monograph dealing with introduction, occurrences, preparation, chemical properties, physical constants, manufacturing details and the relevant literature references, including information on commerce and trade. The write-ups on all the topics are informative and authoritative. Some of these, such as those on musk odorants, ionones, coumarins, etc., are sufficiently elaborate to be useful both to chemists engaged in the trade or in academic activities. The book is a very welcome publication; the author and the publishers deserve our compliments.

S. C. BHATTACHARYYA

STUDIES IN PETROCHEMICALS: Vols. 1 & 2 (United Nations, New York), 1966. Pp. xi+568 & viii+569-1078. Price $ 25.00

The two volumes on *Studies in Petrochemicals*, running to 1078 pages, contain papers and discussions submitted to the First United Nations Inter-regional Conference on the Development of Petrochemical Industries in Developing Countries, held in Tehran (Iran) during 16-30 November 1964. The papers fall broadly under four categories: (i) General background of the petrochemical industry which includes the characteristics of the development of this sector, market for petrochemical products, trends in research and technological developments; (ii) Industry studies dealing with manufacture of petrochemical raw materials (olefines, diolefines and aromatics) and manufacture of different petrochemical products such as nitrogenous fertilizers, plastics, synthetic fibres, synthetic rubbers and other special products; (iii) Country studies, comprising papers from different countries reviewing the development of petrochemical industry in each; and (iv) Financial, locational and developmental aspects including regional development of petrochemical industry.

The problem of supply of suitable feedstocks for olefine plants was discussed in many papers; the preferred feedstocks were natural gas and naphtha. The problem did not relate as much to the technology of conversion as to pricing and adequacy of supplies in the world market. Interesting papers were presented, reviewing current technical developments in the production of petrochemical intermediates, e.g. recovery of aromatics and synthetic fibre intermediates. Some newer subjects were also reviewed, e.g. synthetic lysine as byproduct in caprolactam manufacture developed by Dutch State Mines and proteins from fermentation of petroleum hydrocarbons by British Petroleum Company.

The papers contain a series of very valuable studies made by the United Nations Centre for Industrial Development, and the Institut Francais du Petrole, giving detailed reviews of petrochemical developments, and many techno-economic case studies.

The country studies show that almost every developing country was planning to establish petrochemical industries. Policies of different countries towards raising resources, attracting foreign capital, procurement of feedstocks and organizing the industry were discussed. The country study from Mexico was interesting as it explained the government policy to organize petrochemical industry, viz. the first generation petrochemical raw materials to be wholly produced by the government; the second generation products, partly by government and partly by private companies; and the end-products wholly by private industry.

Large internal markets, high capital investment and high level of technical development characterize the petrochemical industry in developed countries. These are precisely the conditions that operate adversely in developing countries, with their limited market demands and resources. Several papers reviewed growth of markets in developed countries for petrochemical products and the trends in petrochemical production. As the main influence of technological developments was to enable installation of large size units, thereby reducing cost of production of olefines and derived products, economy of size of olefine plants was discussed by many authors. Single ethylene plants of 100,000 tons per annum capacity were proving attractive. It was interesting to observe diametrically opposite views being expressed, all for the consideration of the developing countries in regard to economic sizes of plants; some commercial firms advocated large plants due to their low production costs, whereas others justified relatively small size units, as being economic considering the limited resources in developing economies. This aspect was particularly discussed in connection with manufacture of ammonia and ethylene.

It was in this conference that the proposal was openly made for the first time that India should import large quantities of liquid ammonia from the Middle East where it could be manufactured from oilfield gases which are now being flared and are, therefore, valued at practically no price. There was considerable difference of opinion between the representatives of India and those of others supporting the move. Subsequently this proposal has gained support in India.

The proceedings of such a conference naturally take time to get published, diminishing the relevance of some of the economic calculations. On the other hand, most of the information is of lasting value, because the papers discussed trends and developments, and methods of approach in analysing complex projects such as those encountered in petrochemical sector. The introductory parts in some papers were so elementary as to justify deletion.

The volumes will prove an extremely valuable source of information for any country interested in development of petrochemical industry. It is expected that the second conference will take place this year and it is hoped that valuable contributions will again be made.

M. G. KRISHNA

NOTES & NEWS

A theory of universal primary interactions

A theory of universal primary interaction of particles, including strong, electromagnetic and weak interactions, has been proposed [*Nature, Lond.*, **216** (1967), 979]. In this theory, four families of particles and their associated fields have been distinguished. The characteristic interaction properties of the families are as follows:

Family	*Particles*	*Interactions*
Lepton	e, μ, ν_e, ν_μ	Weak, electromagnetic
Photon	γ	Electromagnetic
Baryon	p, n	Strong
Meson	$\pi, \eta, A_1, \rho, \omega, \phi, E, D$	Strong, electromagnetic, weak

Nuclear forces and nuclear β-decay were attributed to mesons by Yukawa. The present scheme accommodates many mesons, pseudoscalar, vector and pseudovector. Consequently, the nuclear forces which are obtained have three characteristic ranges. The largest range is the result of pion exchange. The vector and pseudovector mesons lead to shorter range potentials, but they also lead to spin-orbit forces which are essential to have an understanding of the nucleon-nucleon interaction. Both in complex nuclei and for nucleon-nucleon scattering at higher energies, they were phenomenologically introduced with great success.

The most important idea underlying the present theory is that the primary interactions of the baryons consist of the strong universal coupling to vector and axial vector fields only. Both electromagnetic and weak interactions of the baryons are acquired characteristics. Thus, this theory is the logical completion of the idea that the β-decay of the nucleon arises only by virtue of its coupling to the meson. Such diverse phenomena as NMR, ratio of the Gamow-Teller and Fermi coupling constants, weak magnetism, absence of neutral lepton currents, apparent suppression of strange particle leptonic decays, pion-nucleon scattering lengths, and the salient features of nuclear force are quantitatively accounted for by the present theory.

Two-photon spectrum of a liquid

The two-photon absorption spectrum of a liquid, as distinguished from the two-photon absorption spectra of crystals, has been observed [*Phys. Rev. Lett.*, **20** (1968), 93]. The optical absorption spectrum of a fluid is primarily determined by the electronic states of the free molecules. Earlier attempts to observe this two-photon absorption in liquids had failed because of a frequency-independent, long-lived (1 μsec.) absorption, which is due to suspended submicron particles. This difficulty has been obviated in the present work by repeated filtration with successively finer (~100 A.) millipore filters to obtain an extremely clean sample of liquid α-chloronaphthalene. This liquid was chosen for its amenability to purification, resistance to oxidation and for possessing an absorption band in a region easily accessible to the ruby-laser xenon-flashlamp sources. A 14 cm. pathlength cell was used in the two-photon spectrometer with a typical laser power of 10 MW.

The proof that the absorption spectrum obtained is of the two-photon type lies in the fact that the absorption temporarily follows the laser pulse accurately. It has also been verified that the absorption is linearly proportional to the intensity of the laser pulse.

From the one- and two-photon spectra, the latter was found to contain two bands: a fairly weak transition appearing as a shoulder at 35000 cm.$^{-1}$ and a strong peak at 42000 cm.$^{-1}$. As distinguished from this, the one-photon spectrum showed a one-photon electronic state at 35000 cm.$^{-1}$ but none corresponding to the peak at 42000 cm.$^{-1}$.

An important result of this work is the observation and assignment of a molecular '*g*' excited state which is not detectable by one-photon spectroscopy or even by two-photon spectroscopy of crystals.

Standard for thermal neutron flux density

A standard for thermal neutron flux density has been established by the Electronics Division of the Bhabha Atomic Research Centre by distributing six americium (241)-alpha-beryllium neutron sources (emission rate of each source is approximately $1 \cdot 1 \times 10^6$ neutrons/sec.) inside a graphite stack ($160 \times 120 \times 150$ cm.).

The stack contains a small air cavity ($4 \times 4 \times 15$ cm.) centrally situated with respect to these sources for the calibration of neutron detecting foils and small chambers and counters. For bigger size detectors, a $6 \times 6 \times 75$ cm. channel can be provided by removing the central graphite rod.

The thermal neutron flux density in the cavity has been absolutely determined in terms of the gold cross-section by $4\pi\beta-\gamma$ coincidence counting of irradiated high purity gold foils. The thermal neutron flux density below the cadmium cut-off energy is estimated to be 6438 neutrons per sq. cm. per sec. with an uncertainty of $\pm 1 \cdot 8$ per cent.

The flux standard has been directly compared with the standards maintained at the National Bureau of Standards, Washington, and the Electrotechnical Institute, Tokyo, under a programme organized by the International Bureau of Weights and Measures, France. In this way the standards maintained by eleven international laboratories will be compared [*Nuclear India*, **6** (No. 8) (1968), 1].

Powder diffraction spectrography

A new high speed technique based on X-ray spectrography has been developed at the Massachusetts Institute of Technology for obtaining lattice spacings of powder samples in times potentially as short as 1 sec.

A diffractometer having a Siemens X-ray source (Fe anode, 8 ma. at 45 kV.) was combined with a lithium drifted Si[Si(Li)] semiconductor detector connected to a 4096-channel pulse height analyser. A low energy photon spectrometer consisting of a Si(Li) detector and a field effect transistor preamplifier formed the detection system, the whole system being cooled by liquid nitrogen. Pulses from the preamplifier were passed through a TC-200 amplifier and stored in a 4096-channel pulse height analyser and the amplifier gain adjusted such that the energy region 0-64 keV. was spread over 1024-channel quadrant of the analyser memory. The pulse height-energy curve of the system was determined from spectra of standard sources, e.g. ^{57}Co and ^{241}Am. The diffractometer was set to a low angle θ, and the counts were taken for various periods with Cu, Ag, Re, Rt and Au and counts per channel were plotted against wavelength. To obtain the *d*-spacing, Bragg's law was applied in the form $E = hc/\lambda = 12{\cdot}398/\lambda$ where E is the photon energy expressed in keV. This leads to $|K| = (\sin\theta/6{\cdot}199)E$ showing the proportionality of the reciprocal lattice vector to the energy of the diffraction peak. An exposure of 5-10 min. was used for these experiments and the results obtained have an uncertainty factor of about 0·18 per cent. Both the duration of the exposure and the error could be further brought down by proper instrumentation.

With conventional X-ray diffraction equipment provided with a scintillation counter for direct recording, the recording of powder diffraction patterns of polycrystalline materials with reasonable resolution takes considerable time. This is because the scanning rate cannot exceed a certain limit set by the slit width and the signal to noise ratio. Therefore, recourse to image amplification or electron diffraction had to be taken to obtain diffractograms in short intervals. But in cases where these are difficult to use, e.g. rapid transformation of metastable alloy phases, this new technique could be profitably used. To follow rapid transformations a series of spectra are to be taken and they can be stored in the analyser memory or recorded on magnetic tapes.

The new technique can also be used to study crystals under high pressure, for it requires only an one beam-exit port which can be a convenient chosen angle θ, unlike the conventional powder method permitting a range of θ values [*Science, N.Y.*, **159** (1968), 973].

Accelerators — A new tool for mechanistic studies

Chemical accelerators have been used for the first time to study reaction mechanisms in the energy region 1 eV. and above. Dr R. L. Wolfgang and coworkers of the Yale University have used two different chemical accelerators analogous to high energy accelerators used in nuclear smashing; one is EVA (evatron), used for studying reactions between ions and molecules, and the other, ADAM, for the study of reactions between hydrogen atoms and molecules.

These accelerators use the beam technique wherein monoenergetic beams of the species taking part in the reaction collide at an angle of 90° and the resultant scattering of products and reactants are subjected to measurements of angular distribution and kinetic energies with the aid of a built-in mass spectrometer and a stopping-potential analyser.

The energy of the reactant ion beam can be varied from 25 to 0·7 eV. in EVA and from 200 to 1 eV. in ADAM, which means a relative energy of collision as low as 0·1 eV. can be achieved in these accelerators. The thermal method used in the past for studying energetics of chemical reactions is essentially heating the reactants till the reaction sets in; considering the facts that a temperature of 1000°C. corresponds to 0·1 eV. and that the strengths of the chemical bonds that are ruptured in chemical reactions are in the region of 5 eV., it is clear that only the very bottom of the energy range of chemical reactions could be studied by the thermal method. Some earlier techniques used in hot atom chemistry like nuclear recoil are of very limited application and cannot help in the formulation of detailed mechanisms. Therefore, the new technique is a definite advancement in the study of reaction mechanisms.

Two simple ion-molecule reactions that have been extensively studied earlier by conventional methods have been studied with EVA : $Ar^+ + D_2 \rightarrow ArD^+ + D$ and $N_2^+ + D_2 \rightarrow N_2D^+ + D$.

On the basis of the results obtained, a new model for ion-molecule reactions has been suggested. The force of attraction between the ionic charge and the dipole it induces in the molecule causes the reactant, say Ar^+ and D_2, to be accelerated towards each other. At the distance of the closest approach a D atom is transferred and ArD^+ formed induces a dipole moment in the free D atom, thereby decelerating the products as they recede from each other. The product energies and angular distributions predicted on the basis of this model are in excellent agreement with the experimental results. The distance of the closest approach between Ar^+ and D has been found to be the same as the bond distance in DCl molecule, which has the same electronic configuration as ArD^+.

Tritiation of cyclohexane has been studied using ADAM by colliding hot monoenergetic tritium ions with cyclohexane chilled to a solid with liquid nitrogen. The products are volatilized and analysed by radio-chromatography for tritiated products, mainly tritiated cyclohexanes and a little tritiated *n*-hexane and hexenes, which are shown in curves as a function of kinetic energy per tritium atom. The threshold energy for replacing a H with T in cyclohexene has been found to be 1 eV. and the yields increase steeply and level off to a maximum at 10 eV. This is the first time the threshold energy of a hot reaction involving only neutral species has been measured [*Chem. Engng News*, **46** (No. 10) (1968), 42].

A novel fluidized bed electrode system

A new electrode system, based on fluidized bed principle and designed at the University of Newcastle-upon-Tyne, is claimed to have higher efficiency than the conventional designs. The basis of the development is that if a fluid is passed upwards through a layer of evenly sized particles at a uniform speed, the particles lift up and float like a quasi-fluid in a stable dynamic balance, the stabilizing force being gravity. One of the characteristics leading to stability is the fact that none of the particles touch one another; the fluid flows round all surfaces of all particles at the same time.

Theoretically, the above considerations would mean that if conducting particles are suspended in a nonconducting fluid, no current would flow between the conducting particles. The discovery made at Newcastle proves this theory to be wrong. A remarkably uniform current is seen to flow without changing the flotation stability and without any breakdown at high current densities. Replacing the nonconducting fluid with an electrolyte, a fluidized bed is obtained which behaves electrochemically as a single uniform electrode.

It has been demonstrated experimentally that in such an electrode the whole of the superficial area of all the particles works as an electrode surface. This implies that the throughput of an electrochemical process can be stepped up by any volumetric increase of the electrode [*Spectrum*, (No. 40) (1967), 11].

Microdetermination of monoamine oxidase

The conventional methods for the assay of monoamine oxidase based on the measurement of oxygen uptake or ammonia formation are not sensitive enough for organs with low enzyme activities, such as dog heart or for small organs, such as pineal body, carotid body sympathetic ganglion, etc. A sensitive fluorometric method using serotonin as substrate has been reported [*J. Biochem.*, *Tokyo*, **62** (1967), 621].

The method involves measurement of the fluorescence of 5-hydroxyindoleacetic acid formed from serotonin after separation by Dowex-50 column chromatography. The method makes the determination of the monoamine oxidase activity possible even in such small organs as carotid body or pineal body and the whole procedure can be performed within 1 hr.

A mitochondrial fraction prepared by differential centrifugation of rat homogenates in 0·34*M* sucrose is once washed with 0·01*M* potassium phosphate buffer, and dialysed against 1000 times the volume of the same buffer for 3 hr. Similarly, suspensions of mitochondria from human pineal body and carotid body can be prepared in 0·02*M* phosphate buffer (*p*H 7·4). A suspension of the mitochondria equivalent to 0·1 to 10 mg. of protein is incubated at 37°C. in a test tube containing 50 μmoles of nicotinamide, 8 μmoles of NAD, 2·84 μmoles of serotonin, 250 μmoles of phosphate buffer (*p*H 7·4), 0·10 ml. of aldehyde dehydrogenase preparation and water to a total volume of 1·75 ml. At definite intervals, aliquots (5 ml.) are taken out and heated in boiling water for 2 min. After the addition of 3 ml. of chilled distilled water, denatured protein is centrifuged off. The supernatant is passed through the column to remove unreacted serotonin. The column is then washed with 10 ml. of water. One drop of 2*N* NaOH and 0·5 ml. of 1*M* phosphate buffer (*p*H 7·4) are added to the column effluent (13·5 ml.) to adjust the *p*H to 7·4. The fluorescence of 5-hydroxyindoleacetic acid in the neutralized column effluent is then measured directly in an Aminco-Bowman spectrophotofluorometer at 295 mμ excitation and 350 mμ fluorescence. A blank, to which the mitochondria are added after the incubation, and internal standard are carried out to permit direct calculation of results. The recovery of 5-hydroxyindoleacetic acid is found to be 90-95 per cent.

A protein factor regulating the state of aggregation of myosin

A factor named as myosin aggregation factor (MAF) has been isolated from rabbit skeletal muscle [*J. Biochem.*, **62** (1967), 726]. It combines with myosin at low ionic strengths and thus alters dynamically and reversibly the aggregation state of myosin. When MAF is added to myosin in 0·1*M* KCl, spherical aggregates are formed. On the addition of ATP to the mixture, the spherical aggregates are dynamically transformed into a network of filaments. While H-meromycin is insoluble in the presence of MAF at low ionic strengths, it solubilizes on the addition of ATP and insolubilizes again after the splitting of ATP. MAF is salted out from 20-55 per cent saturated ammonium sulphate. It precipitates at *p*H 5·0 and solubilizes in 0·1*M* KCl at *p*H 7·0. It does not permeate through a cellophane tubing and is inactivated by heat treatment at 60°C. for 1 min. Its ultraviolet absorption spectrum exhibits a peak at 280 mμ. It is inactivated by Pronase-P, but not by RNase-A. All these properties show that MAF is a protein.

The effective weight ratio of MAF to myosin is about 1 per cent, but the binding weight ratio is about 10 per cent. The remarkable difference observed in these two weight ratios may be attributed to the aggregation of myosin to filaments under the conditions of the experiment. Thus, MAF appears to act as a cementing substance among filaments of myosin. MAF differs from the other myofibrillar proteins in its inactivation at 60°C., resistance to trypsin and ammonium sulphate fractionation. Like F-actin, MAF is precipitated by ultracentrifugation at 35000 r.p.m. for 3 hr; the activity of MAF is strongly reduced by dialysis against ATP, thereby suggesting it to be possibly a complex of F-actin with other proteins, though the reconstitution of the complex may be prevented by the presence of proteins other than the components of MAF, when actin is transformed into the F-form after its depolymerization by ATP.

Preparation of cytochrome oxidase using non-ionic detergent

A simplified procedure for the isolation of a lipid-containing cytochrome oxidase preparation from beef-heart mitochondria has been developed [*Biochim. biophys. Acta*, **143** (1967), 639-41]. In the new method, unlike in the existing methods which involve the use of Triton X114 and Triton X100 as solubilizing agents and oxogenous phospholipid for their maximum activity, only Triton X100 is used as the solubilizing agent and non-ionic detergent as the activity stimulant. The method gives a high purity preparation in good yield in a minimum time (5 hr). In addition, it permits a study of the effects of detergent and salt separately, which is not possible with the preparation obtained using the existing methods.

Beef-heart mitochondria, isolated by the method of Löw and Vallin [*Biochim. biophys. Acta*, **69** (1963), 361], are suspended in 0·25*M* sucrose containing 0·01*M* potassium phosphate (*p*H 7·4) and subjected to sonic irradiation for 3 min. The middle yellowish fraction obtained after centrifugation at 30000 *g*. for 30 min. is suspended in sucrose phosphate buffer, homogenized and the protein concentration is adjusted to 30 mg./ml. Enough aqueous solution of Triton X100 (10 per cent, wt/vol.) is added, with vigorous stirring, to achieve the final concentration of 1 mg./mg. of protein. After adding solid potassium chloride (1*M*), the mixture is allowed to stand for 10 min. at 0°C. and centrifuged at 40000 r.p.m. for 30 min. in a Spinco preparative ultracentrifuge. Of the two fractions thus separated, the green residue is collected, resuspended in sucrose phosphate buffer and the protein concentration is adjusted to 20 mg./ml. Enough of aqueous Triton X100 is added again to the suspension to make 1 mg./ml. protein and potassium chloride to 1*M*. The mixture is centrifuged at 40000 r.p.m. for 30 min. and the green residue is collected and resuspended. The second treatment causes some loss of the oxidase activity, but is necessary to free the final preparation from any cytochromes *b* or c_1. Essentially the same treatment is used to solubilize cytochrome oxidase from the second residue. The dark brown residue is discarded and the green supernatant fraction is collected and stored at −20°C. The final preparation is optically clear and quite stable at this temperature. The preparation contains the same amount of heme as the lipid-deficient preparation obtained by the existing methods. The phospholipid content is substantially higher (20 per cent) and the yield is about 50 mg./g. of starting sonicated mitochondria.

Nature of myosin molecule

Though it has been known for some time that myosin consists of a long shaft (some 1400 A. by 20 A. thick) with a globular head at one end, till recently there was difference of opinion regarding the number of long polypeptide chains contained in the myosin molecule — two according to one view and three according to another. This discrepancy now appears to have been resolved by Slayter and Lowey [*Proc. natn. Acad. Sci., U.S.A.*, **58** (1967), 1611] who have, for the first time, shown by combining the technique of rotary shadowing with electron microscopy, two heads instead of one in rabbit myosin molecule, thereby suggesting the presence of two similar chains in the myosin molecule.

The observation that heavy meromycin fragment (head and one-third shaft), the proteolytic fragment of myosin, cleaves further to two subfragments, electron microscopically identified as a truncated myosin and globules respectively, provide further evidence in support of the above contention.

Although this study has accounted for the heavy proteolytic fragment of the myosin, nothing definite has been known about the role of lightweight fragments which are liberated on denaturation and without proteolysis. In fact, it has not been properly established whether these fragments of the low molecular weight form an integral part of the myosin molecule, or are merely bound extraneous components [*Nature, Lond.*, **216** (1967), 540].

Clays and Clay Minerals

From an annual proceedings volume, *Clays and Clay Minerals* has been converted into a bimonthly journal. The journal covers mineralogy, soil science, physical and colloid chemistry, ceramics, agronomy, stratigraphy, paper chemistry, and many branches of engineering. The annual subscription is £ 16 16*s*.

Engineering Fracture Mechanics

This new quarterly serves as the principal publication medium for the technical papers presented at the Annual National Symposium on Fracture Mechanics. The journal covers crack toughness evaluation, fatigue, stress corrosion cracking and adhesion science. The annual subscription is £ 24 7*s*.

Central Food Technological Research Institute, Mysore

The annual report of the Institute for 1966 reveals that 36 research projects were completed and 27 new projects started during the year; at the end of the year 53 research projects were in hand. A Sensory Evaluation Unit for evaluating various products developed at the Institute was set up during the year. A survey on the problems of the cashew processing industry in Kerala and Mysore and another on the potential for a fish processing industry in Gujarat were carried out. Among the significant achievements during the year were the preparation of complete project reports for setting up an egg powder plant and two vegetable dehydration units and the development of know-how for the detoxification of groundnut flour and protein isolate contaminated with aflatoxin.

A new fumigant combination based on ethylene oxide, methyl bromide and ethylene dibromide (1:1:1, wt/wt) has been developed for the fumigation of protein-rich oilseed cakes, oilseeds and pulses. A new technique developed for refilling used cans with Durofume 1:1 (ethylene dibromide : methyl bromide) reduces the cost on transport and cylinders. A method has been developed for assessing the fumigant concentration in air. A bactericidal and fumigicidal combination of gaseous sterilants based on ethylene oxide, methyl bromide and ethylene dibromide (1:1:1, wt/wt) has been developed. Application of the new combination reduces the quantity of bromide residues in protein-rich oilseeds, oil cakes and powdered products and also reduces the risks arising from inflammability of ethylene oxide.

A rapid method for the identification of different calcium phosphates (being tried as insecticides) based on progressive heating up to 1000°C. with a temperature programming of 15°C./min. and the characteristic dehydration curves of the compounds has been developed.

A simple procedure for the mass rearing of a depteran fly, *Megaselia scalaris* Loew., for use as test insect in the bioassay of insecticides has been developed.

In respect of sensitivity to microfilms of phosphatic insecticides, the susceptibility of this fly has been found to lie between those of the housefly and pomace fly (*Drosophila melanogaster* Meig.). A technique for separating mites from infested products and quantitatively estimating them has been evolved. This should prove as an aid in quality assessment of processed foods.

A simple unit for splitting *dal* (after dehusking and conditioning) into two halves without breakage has been designed and fabricated. A procedure for preparing superior quality sandwich type of bread has been developed. A complete commercial parboiling unit has been fabricated for a modern rice mill set up at Mandya. In addition to this, blueprints for the fabrication of improved parboiling units have been supplied to 8 firms. The project on the evaluation of the performance of rice mills has yielded valuable results for evolving a sound rice milling policy for the country. Stress has been laid on the importance of establishing efficient units which would be large enough to utilize all the byproducts.

Pilot plant studies have been undertaken on the production of a roller dried weaning food based on vegetable raw materials, production of banana powder and solvent extraction of rice bran with hexane.

Changes in physico-chemical properties and the suitability for canning of various varieties of mangoes, guava, apricot, water chestnut, cabbage, cauliflower and peas have been studied. An economical wax emulsion composition containing indigenous sugarcane, paraffin and sisal waxes with or without shellac has been developed. Waxing of carrots, brinjals, snakegourd, ribbed gourd, cucumbers, coccinia, limes, tight-skinned oranges and tomatoes led to 50 per cent increase in their storage life.

A method has been standardized for the manufacture of vinegar from pineapple peel and pomace. The material is passed through a pineapple crusher and the juice extracted in a hydraulic press or hydroextractor (yield 60 per cent); after adjusting the final brix to 10°C., the juice is fermented. The alcoholic juice is then passed through a wooden vinegar generator. Alcoholic fermentation takes 4 days for completion and acetic fermentation another 4 days to convert 400 kg. peel juice into vinegar. The production cost of vinegar brewed by this method works out to 67 paise/bottle.

A simple equipment has been designed for coating eggs with preservative formulations. Whole egg powder (desugared by yeast) from duck/chicken has been produced on a pilot plant scale. Complete desugaring by active dry yeast has been achieved in 1·5 hr at a fermentation temperature of 36°C.

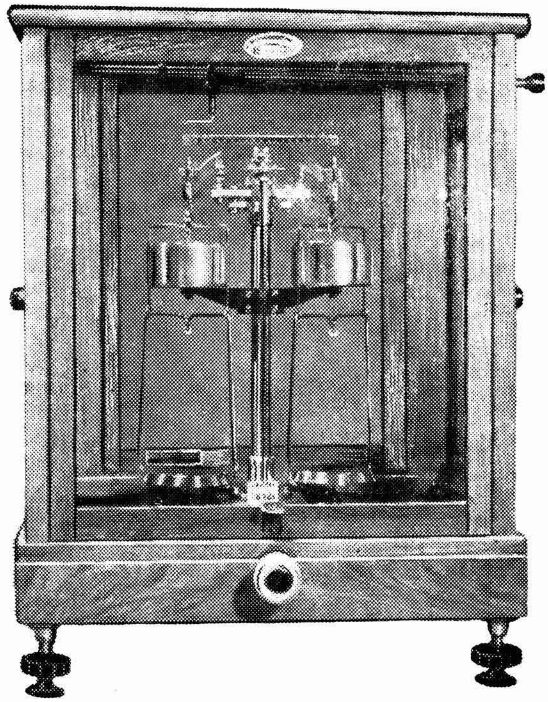
For the preparation of white pepper a new process of softening the skin by cooking for 10-15 min. has been developed. Mechanization and clean processing are the advantages of this process over the conventional one. It has been found that of the various solvents tried, only acetone or alcohol are suitable for satisfactory extraction of piperine and pepper oil from pepper.

The method worked out earlier for the detoxification of peanut meal has been modified to snit pilot plant scale operation for achieving 98-100 per cent destruction of the toxin. Several processes for the production of commercial enzymes (amyloglucocidase from *Aspergillus awamori* CFTRI 1042, and *Rhizopus niveus* CFTRI 1053, amylase from *Aspergillus oryzae* CFTRI 1048, and pectinase from *A. niger* CFTRI 1947) have been developed.

Notable among a large number of processes developed are: (1) a method for decomposing osazones using furfural; (2) a modified method for preparing dinitrophenylosazones using nitrobenzene as reaction medium; (3) a paper chromatographic method for the separation, identification and estimation of pyrrolidone carboxylic acid; (4) a simple method for the estimation of total unavailable carbohydrates and hemicelluloses in foodstuffs; and (5) a process based on the production of ethylene from alcohol and subsequent absorption into bromine for the production of ethylene dibromide (10 kg./day).

Announcements

▪ *A Symposium on Environmental Physics as Applied to Buildings in Tropics* will be held during February 1969 at the Central Building Research Institute, Roorkee. The topics for discussion would be heat and mass transfer through buildings, climatology, daylighting of buildings, and any other items on building physics. Further details can be obtained from the Director, Central Building Research Institute, Roorkee.



'LAB-CHEM'

ANALYTICAL BALANCES & WEIGHTS

for

INDUSTRIAL, RESEARCH & COLLEGE LABORATORIES

Manufactured by

LAB-CHEM BALANCE WORKS

BOMBAY 11

●

Contact Sole Selling Agents:

INDIA SCIENTIFIC TRADERS

DEALERS IN LABORATORY EQUIPMENT
OF EVERY DESCRIPTION

PEERBHOY MANSION
460 SARDAR VALLABHBHAI PATEL ROAD
BOMBAY 4 (BR)

Phone: 356336 Gram: 'Esvijack'

IMPACT OF SCIENCE ON SOCIETY

How science is changing the social, political, economic and cultural structures of today's societies.

ORIGINAL ARTICLES ON

- SCIENCE AS A SOCIAL FORCE
- THE ROLE OF SCIENCE IN DEVELOPING NATIONS
- SOCIAL EFFECTS OF NEW SCIENTIFIC DEVELOPMENTS

Issued quarterly

Annual Subscription :	$ 3.50	21/- stg	12.50 fr.
Per copy :	$ 1.00	6/- stg	3.50 fr.

Free specimen copy on request

Send subscriptions to:

ORIENT LONGMANS LTD.

BOMBAY - CALCUTTA - MADRAS - NEW DELHI

Just issued...

IMPACT—Vol. XVIII (1968), No. 2

Peace research, the science of survival
by Bert V. A. Rölling

Why is Man aggressive? A synthetic Round Table
Participants: Alex Comfort, G. M. Carstairs, Frank Fraser Darling, Kenneth Donald, Philip Noel-Baker, Joseph S. Weiner, Gaston Bouthoul, C. H. Waddington

A data-collecting network for the sociosphere
by Kenneth E. Boulding

Polemology and the solution of conflicts
by Gaston Bouthoul

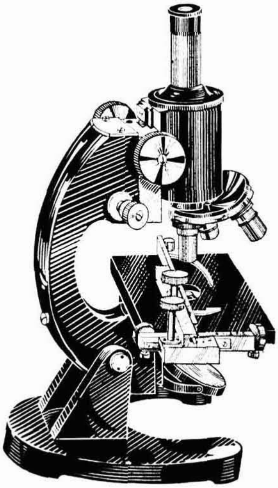
The application of game theory to peace research
by Anatol Rapoport

Ethnocentrism — source and aggravating factor of conflicts
by Ignacy Sachs

UNESCO

United Nations Educational, Scientific and Cultural Organization

Place de Fontenoy, Paris 7e



---

and now . . . Chloromethanes

METHYL CHLORIDE

METHYL CHLORIDE: Finds uses as a catalyst in low temperature polymerisation, such as synthetic rubber, silicons, etc.; as a propellant in aerosal spraytype containers; as a refrigerant; and as a solvent for insecticides.

METHYLENE DICHLORIDE

METHYLENE DICHLORIDE: As a solvent wash for cellulose acetate, in the manufacture of photographic film; as an active agent in various formulations of paint, varnish and carbon removers; as a fumigant; and as a solvent for insecticides.

CHLOROFORM

CHLOROFORM: As an important anaesthetic; and as a solvent for fats, oils, resins and rubber and numerous other substances.

CARBON TETRACHLORIDE

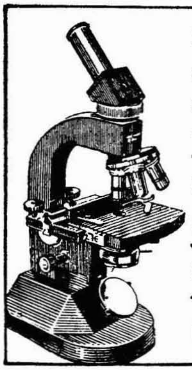
CARBON TETRACHLORIDE: As a degreasing agent; as a good dry-cleaning solvent; as a base for manufacture of fluorochlorocarbon refrigerants and, mixed with carbon disulphide, ethylene dichloride and others, as a grain fumigant and pesticide.

THE METTUR CHEMICAL AND INDUSTRIAL CORPORATION LIMITED

THE METTUR CHEMICAL & INDUSTRIAL CORPORATION LTD.
METTUR DAM R.S., SALEM DIST.
Managing Agents: SESHASAYEE BROS. PRIVATE LTD.

IRL

OPTICAL INSTRUMENTS



microscopes
students' • laboratory
research • metallurgical
dissecting • travelling

microscope attachments

spectrometer

telescope

GHARPURE & CO.
P-36 India Exchange Place Extension, Calcutta-1
Gram : MEENAMO • Phone : 22-2061

Available from Ready Stock

• Balances & Weight Boxes: BOSCH • Calorimeters: HELLIGE-DUBOSCQ (Visual) • Incubator & Oven Combined: MEMMERT • Binocular Research Microscopes: AUGUST-GERMAN • Microtomes Rotary & Minot: ERMA-JAPAN • pH Meters: BECKMAN Model H2 & PHOTOVOLT Model 85 • Test Sieves: ENDECOTT'S B.S.S. & A.S.T.M. • Laboratory Glassware: PYREX, WESTGLASS, CORNING, etc. • Filter Papers: WHATMAN & GERMAN

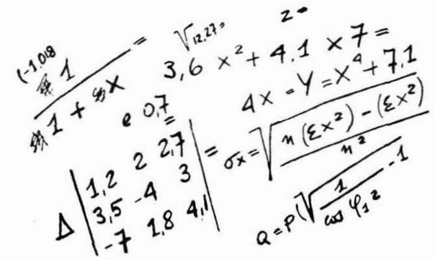
Also Silicaware and Sintered Glassware

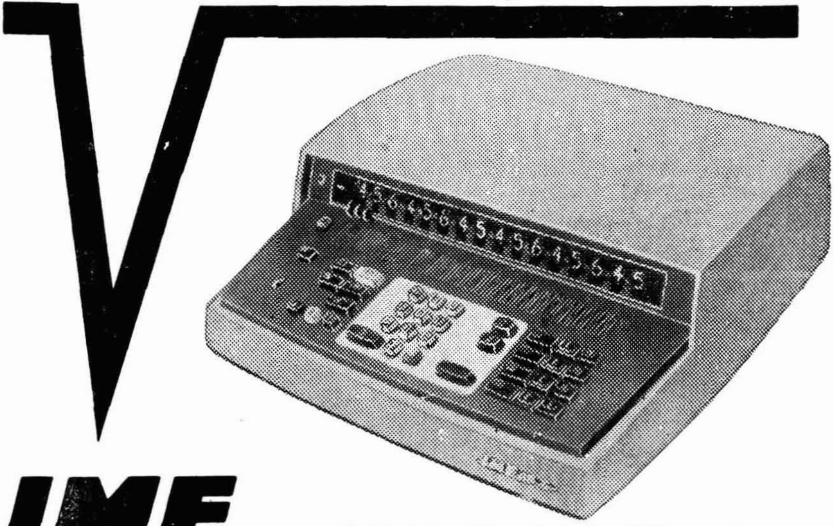
AND

'MODERN' Brand Laboratory Instruments such as Ovens, Incubators, Water Baths, Water Stills, Heating Mantles, Furnaces, Temperature Control Units, Kjeldahl Assemblies, Micro-Kjeldahl Digestion Units, Melting Point Apparatus, Stirrers, Cork Boring Machines, etc.

Please Contact

MODERN SCIENTIFIC INSTRUMENT Co.
48A/48B SADASHIV CROSS LANE
BOMBAY 4
Telephone: 354108 Telegram: 'MODERNCOM'


$\frac{1}{1+x}$ =
$\sqrt{12,27}$ =
3,6 x² + 4,1 × 7 =
e 0,7 =
4x = Y = x⁴ + 7,1
Δ |1,2 2 2,7; 3,5 -4 3; -7 1,8 4,1| =
σx = √(n(Σx²) − (Σx²) / n²)
Q = P(√(1 / cos φ₁²) − 1



New Publications

FISH & FISHERIES

Supplement to the Wealth of India—Raw Materials: Vol. IV

This well-illustrated supplement provides information in an easy-to-grasp form on: (i) zoological names of 376 fishes of economic value, found in Indian water, along with their English names; (ii) description and distribution of the fishes; (iii) coastal, deep sea and fresh water fisheries; (iv) ingenious devices for catching and preserving fish; (v) fisheries in various States; (vi) manufacture of fish oil and manure; (vii) analytical values of fish-foods and their byproducts; and (viii) marketing practices and data concerning fish trade. An annotated bibliography of 220 references and an exhaustive index are provided.

Pages iv+132 **Demy 4to, 11 plates, including 2 coloured plates; 55 text figures**

PRICE Rs 10.50, Sh 21 or $ 3.00

★

THE MILLIPEDE—THYROPYGUS

CSIR Zoological Memoir No. 1

by

DR G. KRISHNAN

Director, Zoological Research Laboratory, Madras University

This well-illustrated memoir provides information on 10 species of *Thyropygus*. *T. poseidon* Attems is described in detail, the account covering the following aspects: (i) external features; (ii) integument; (iii) skeleto-muscular system; (iv) alimentary canal; (v) blood-vascular system; (vi) excretory organs; (vii) fat body; (viii) repugnatorial glands; (ix) nervous system; (x) sense organs; (xi) neuro-secretory system; (xii) reproductive system; (xiii) larval development; (xiv) water relations; (xv) habit and habitat; and (xvi) affinities. The memoir includes a selected annotated bibliography and an exhaustive index. Instructions for practical work are given, which make the publication more useful for students.

Pages 84 **Royal 8vo; 44 text figures**

PRICE Rs 12.00, Sh 24 or $ 3.50

Copies available from

SALES & DISTRIBUTION SECTION
PUBLICATIONS & INFORMATION DIRECTORATE, CSIR
HILLSIDE ROAD, NEW DELHI 12

PUBLICATIONS & INFORMATION DIRECTORATE, CSIR

PUBLICATIONS

ENCYCLOPAEDIA

Wealth of India: Raw Materials

Vol. III (D to E)	Rs 22.00	Sh 44	$ 6.60
Vol. IV (F to G)	Rs 25.00	Sh 50	$ 7.50
Vol. V (H to K)	Rs 30.00	Sh 60	$ 9.00
Vol. VI (L to M)	Rs 40.00	Sh 80	$ 12.00
Vol. VII (N-Pe)	Rs 30.00	Sh 60	$ 9.00

Wealth of India: Industrial Products

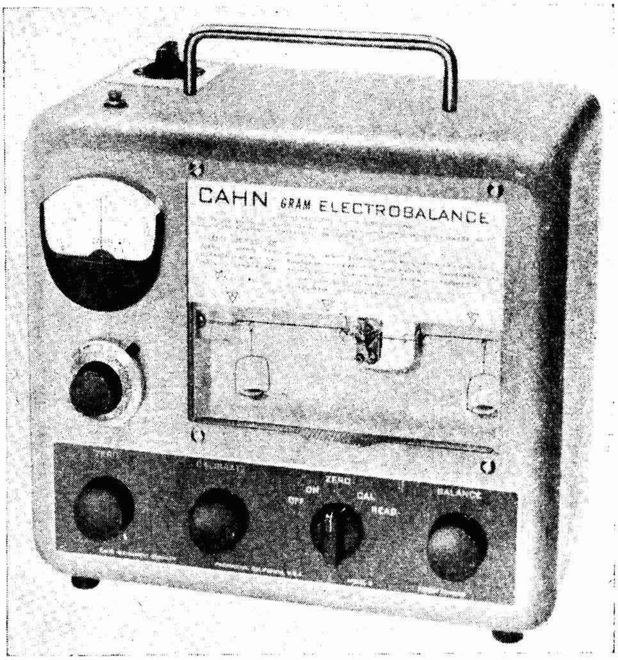
Part III (D to E)	Rs 25.00	Sh 50	$ 7.50
Part IV (F to H)	Rs 25.00	Sh 50	$ 7.50
Part V (I to L)	Rs 30.00	Sh 60	$ 9.00
Part VI (M-Pi)	Rs 28.00	Sh 56	$ 8.00

BOOKS & MONOGRAPHS

Aquatic Angiosperms — A Monograph by K. SUBRAMANYAM	Rs 20.00	Sh 40	$ 6.00
Coir: Its Extraction, Properties and Uses	Rs 6.00	Sh 12	$ 1.75
Flora of Delhi by J. K. MAHESHWARI	Rs 28.00	Sh 56	$ 8.00
Glossary of Indian Medicinal Plants by R. N. CHOPRA, S. L. NAYAR & I. C. CHOPRA	Rs 8.00	Sh 16	$ 2.50
Indian Scientific and Technical Publications — A Bibliography	Rs 25.00	Sh 50	$ 7.50
Indian Essential Oils — A Review by A. K. MENON	Rs 7.00	Sh 14	$ 2.00
Marsilea — A Monograph by K. M. GUPTA	Rs 16.00	Sh 33	$ 5.00
Kinetics of Electrode Processes and Null Points of Metals by L. I. ANTROPOV	Rs 5.00	Sh 10	$ 1.50
Problems relating to the Development of Internal Combustion Engine in India	Rs 12.00	Sh 24	$ 3.50
Essential Oils and Aromatic Chemicals	Rs 10.00	Sh 20	$ 3.00
Cellulose Research: Vol. I	Rs 6.00	Sh 12	$ 1.75
Cellulose Research: Vol. II	Rs 12.00	Sh 24	$ 3.50
Antibiotics — Their Production, Utilization and Mode of Action	Rs 15.00	Sh 30	$ 4.50
Chemical Process Design — A Symposium	Rs 18.00	Sh 36	$ 6.00
International Geophysical Year: Vol. I — Symposium Proceedings	Rs 18.00	Sh 36	$ 6.00
International Geophysical Year: Vol. II — Symposium Proceedings	Rs 18.00	Sh 36	$ 6.00
Plant Embryology — A Symposium	Rs 20.00	Sh 40	$ 6.50
Low Temperature Carbonization of Non-caking Coals and Lignites and Briquetting of Coal Fines — A Symposium: Vols. I and II each	Rs 35.00	Sh 70	$ 11.00
Nucleic Acids	Rs 20.00	Sh 40	$ 6.00
Patented Inventions of CSIR (1940 to 1964)	Rs 16.00	Sh 33	$ 5.00
Recent Advances in Polymers by H. F. MARK	Rs 2.50	Sh 5	$ 0.75
Drug Addiction: with Special Reference to India by R. N. CHOPRA & I. C. CHOPRA	Rs 12.00	Sh 24	$ 3.50
Indian Scientific and Technical Publications (A Bibliography, 1960-65)	Rs 18.00	Sh 36	$ 6.00
Illustrations to the Flora of Delhi by J. K. MAHESHWARI	Rs 28.00	Sh 56	$ 8.00
Fluidization and Related Processes — A Symposium	Rs 24.00	Sh 48	$ 8.00
Indian Fossil Pteridophytes: A Monograph by K. R. SURANGE	Rs 23.00	Sh 46	$ 8.00
CNS Drugs — A Symposium	Rs 33.00	Sh 66	$ 10.00

Can be had from

THE SALES & DISTRIBUTION SECTION
PUBLICATIONS & INFORMATION DIRECTORATE, CSIR
HILLSIDE ROAD, NEW DELHI 12



Printed and published by Shri A. Krishnamurthi, Publications & Information Directorate, Council of Scientific & Industrial Research, New Delhi, at the Catholic Press, Ranchi, India

Regd No. PT-842