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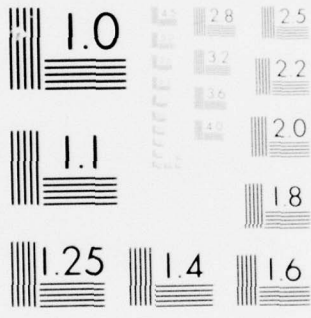
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LONDON

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London

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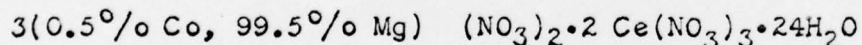
No. 7 - 5

ACHIEVEMENT OF NUCLEAR POLARIZATION

A group of low temperature and nuclear physicists consisting of E. Ambler, M.A. Grace, H. Halban, N. Kurti, H. Durand, C.E. Johnson, and H.R. Lemmer has recently succeeded in producing polarization of cobalt nuclei at the Clarendon Laboratory, Oxford University. They have made use of the method suggested by Rose and Gorter in which the polarization is produced by the magnetic hyperfine interaction between electron and nuclear spins in a paramagnetic ion; the electron spins being polarized at a low temperature by a weak external magnetic field.

Technique

The procedure employed adiabatic demagnetization of several single crystals of a complex salt starting at 1°K. The crystals used weighed a total of four grams and had the following composition:



The function of the cerium in the crystal was that of cooling agent and the cobalt included 50 μ C of radioactive Co⁶⁰. The single crystals were arranged with their crystallographic axes parallel. An external magnetic field of 25 kilogauss was applied along the direction in which cerium has a large g-value. This field was then reduced to zero in a normal adiabatic demagnetization. Immediately following the demagnetization, a weak polarizing field of about 250 to 500 gauss was applied along the direction in which the cerium ion has a very low g-value. Consequently the resulting polarization was achieved with only a very small temperature rise.

Results

The degree of polarization was determined from the observed angular distribution, $I(\theta)$, of the gamma rays from Ni^{60} . Geiger-Muller tubes placed along the polarizing field, and perpendicular to it, were used to count the gamma radiation. Anisotropies, $\frac{I(\pi/2) - I(0)}{I(\pi/2)}$, as high as 50 per cent were observed before the sample had time to heat appreciably.

Relation to Previous Experiments

The Oxford low temperature and nuclear physics groups have previously been successful in demonstrating the existence of anisotropic angular distributions of gamma radiation from the Co^{60} and Co^{58} decays at low temperatures. (See for example Nature 168, 780 (1951)). In these experiments, however, polarization of the nuclear spins was not achieved. The method employed earlier was one suggested by Bleaney. In place of polarization the anisotropic gamma ray distribution resulted from a distribution of nuclear spins between magnetic sub-states in which magnetic quantum numbers $\pm m$ are equally probable. This type of population has been termed alignment and is produced at low temperatures by the strong crystalline electric field of a Tutton salt without the use of an external magnetic field.

EXPERIMENTAL ASTROPHYSICS

Ingenious and stimulating experiments are being carried out by Professor W. Lochte-Holtgreven at the University of Kiel on various problems in astrophysics. He has been developing techniques designed to produce laboratory conditions similar to those prevailing on the surface of stars or the sun.

Spectroscopic investigations are in progress at extremely high effective temperatures which are produced in a water-cooled electric arc. The results obtained on hydrogen confirm the theory that sunlight is produced by electrons moving in the field of neutral hydrogen atoms, or by attaching themselves to neutral hydrogen atoms leading to the formation of a negatively charged hydrogen ion (cf. ESN, 5, 172 (1951), Z. f. Phys., 133, 124 (1952)).

A simple laboratory experiment was used to demonstrate the existence of a magnetic field under conditions analogous, but on an extremely reduced scale, to those prevailing in sunspots. In this work bursts of an ordinary gas flame are injected tangentially at the end of a glass tube and then proceed downward along a screw-like path. The lower part of the tube is surrounded by a pickup coil. When small quantities of metallic sodium or potassium are injected into the flame they are ionized, and due to the friction with the glass wall a spatial separation of the cations from the electrons takes place. This results in the production of bursts of a magnetic field in the tube, the strength of which is estimated to be of the order of 10^{-4} gauss.

AN INTEGRATOR PHOTOMETER FOR X-RAY DIFFRACTION

Mr. B.S. Fraenkel, working under the direction of Professor E. Alexander at the Physics Department of the Hebrew University, Jerusalem, has developed an instrument for reading automatically and with high accuracy the intensities of an X-ray pattern on a photographic plate. These investigators feel that their method is capable of a higher accuracy than can be obtained by visual matching of pattern spots with calibration.

A particularly useful feature of the apparatus is one which allows a linear measurement of the number of X-ray photons in spite of the logarithmic density-exposure characteristic of the film. This linearity is obtained by setting up a voltage discriminator arrangement so as to compensate for the density-exposure characteristic of the photographic emulsion. Each plate carries an intensity scale, which is obtained by means of a standard stepped wheel exposure, for the purpose of calibrating and setting up of these voltage discriminators.

The plate is mounted in the apparatus and is scanned by a pulsed light beam which has a diameter of 0.2 mm. According to the program which is set up, an area of 2 x 2 mm is scanned at 100 points. The transmitted light beam is detected photoelectrically. The output pulse of the photomultiplier is then applied to a ten-channel voltage discriminator network and counting circuits are used to record the amplitude of the output pulse.

The method is thus somewhat analogous to a pulse height analyzer used in nuclear physics, combined with a simple analogue computer.

DIVIDED DRIFT TUBE FOCUSING SYSTEM

A novel system for improved focusing of a proton linear accelerator has been developed recently by Dr. J.S. Bell of the Atomic Energy Research Establishment, Harwell.

The idea is similar to the principle discovered at Brookhaven for improved focusing and uses alternative sections with strong focusing and strong de-focusing to give a net positive focusing effect.

It is planned to divide the cylindrical drift tubes of the Berkeley-type linear proton accelerator into four quadrants by means of longitudinal cuts in the cylindrical surface. If these cuts are small, the r.f. field will not penetrate to the center of the tube, and the shielding action will be unimpaired. Electrostatic voltages are now applied so that opposing sections are at the same potential, but between adjacent sections there is a potential difference. Near the center of the system the potential, with an obvious choice of axes, will have the form

$$\phi = 1/2 A (x^2 - y^2);$$

by suitably shaping the inner surfaces of the drift tube (e.g. in the shape of rectangular hyperbolae) the region over which the field is substantially of this form may be increased. Such a potential gives a focusing force $E_x = -Ax$ in one plane and a de-focusing force $E_y = Ay$ in the other.

Overall focusing now results, if after every few drift tubes the field is rotated through a right angle, or alternatively if it is rotated by a small angle between successive drift tubes. For a 200 meter long, 50 - 500 Mev machine operating at 200 megacycles, one requires potentials of about 12 kV over 0.5 cm gaps.

These first considerations look very promising. Present theoretical work is concerned with tolerance in the initial beam diameter and divergence, the effect of non-linearity in the radial fields, coupling between phase and radial motion, the criticality of various dimensions, and the effect of the variation of parameters (such as section length) with phase velocity.

THE AGE OF METEOR STREAMS

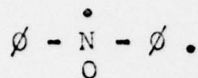
Some interesting observations on radar reflections by meteor showers were reported during the International Astronomical Union Conference in Rome by Mr. B.A. Lindblad of the Lund Observatory, Sweden. In collaboration with Professor O.E.H. Rydbeck's group of the Chalmers University, Gothenburg, he has conducted observations on meteor showers by means of a 100 kw radar set working on 9.1 meter wave length. The arrangement was set up at the new Swedish Radio Astronomy Center in Raö near Gothenburg (ESN 6, 35 (1952)). During the summer months of 1950, observations were made on the δ -Aquarid and Perseid meteor showers. When plotting the numbers of reflections as a function of time, a sharp peak was found preceding by about three days the peak which was associated with the visual observation of the δ -Aquarid meteor shower. If separate plots are made of the long duration echoes from the δ -Aquarid shower and of the short echoes (total echoes minus long duration echoes), this precursor peak stands out very clearly. Lindblad identifies the short duration echoes with small meteors and the long duration echoes with large meteors.

At the time of formation of the meteor stream both large and small meteors occupied the same orbit. The Poynting-Robertson effect, however, which acts in the vicinity of the sun, produces an effect primarily on the smaller particles which will cause their orbits to become progressively smaller and their periods to become progressively shorter with each revolution around the sun. This spread of time between the periods of large and small meteors has now been observed, and from it can be deduced an "age" for the meteor stream which lies between 10,000 and 100,000 years. The details of this research have been published in the Transactions of the Chalmers University, Number 129 (1952).

PARAMAGNETIC RESONANCE OF FREE RADICALS

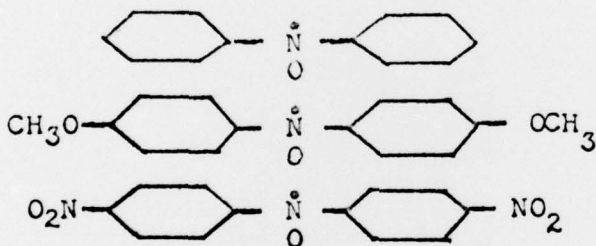
The paramagnetic resonance of organic free radicals is being investigated under the direction of Professor L.J. Oosterhoff in the Department of Organic Chemistry at Leiden, in collaboration with the Kammerlingh Onnes Laboratory. The Landé g factor for the unpaired electron in the free radicals studied can be used as a measure of the "freedom" of the unpaired electron. The calculated value for a "free" electron is 2.0024. American investigators have observed a value of 2.0036 for the diphenylpicrylhydrazyl (DPPH) free radical indicating that the electron can move about this molecule quite freely. Recent investigations in Leiden have dealt with free radicals of the

type



In addition the DPPH radical in benzene was reinvestigated and the measurements extended to 4°K. The five resonance peaks previously reported (Hutchinson et al., J.Chem.Phys., 20, 534 (1952)) appear unchanged down to 20°K. At 4°K however no peaks are observed. The tentative explanation suggested is that the electron spins may be completely frozen and aligned at this temperature; the free radicals would then be antiferromagnetic (cf. Science 116, 527 (1952) for recent American work on possible antiferromagnetism in free radicals).

The Landé g factor was found to be identical, 2.0060, for the following three free radicals:



These are among the highest g values recorded and they suggest that the freedom of the electron may be restricted to the central part of the molecule. It is noteworthy that these three free radicals show very different chemical reactivity; the reactivity is thus not exclusively a function of the electron delocalization.

Further details on this work and other current research efforts in the Department of Organic Chemistry at Leiden are given in Technical Report ONRL-140-52, available from the Technical Publications Office, Code 250, Office of Naval Research, Washington 25, D.C.

STEREOCHEMISTRY OF QUINONE FORMATION

Results obtained by Professor W. Theilacker (Hannover) on the oxidation of phenols to quinones show the importance of both steric and electronic effects in determining the ease of these reactions. The compounds investigated are all derivatives of p,p'-dihydroxydiphenyl. Substitution of increasingly large groups in the ortho position tends to prohibit coplanarity and will make quinone formation more and more difficult. On the other hand substitution of alkyl groups in the meta positions lowers the redox

potential and thus facilitates oxidation to the quinone. It was found that while the o,o'-difluoro and o,o'-dimethoxy compounds can be readily oxidized to the corresponding quinones, the o,o'-dimethyl and o,o'-dichloro compounds cannot be so converted. By filling the four meta positions with methyl groups, the formation of quinones from the two latter compounds is again made possible. If, however, all four ortho positions are blocked by methyl groups, quinone formation again becomes impossible.

THE THERMODYNAMIC ACTIVITY OF CARBON IN LIQUID IRON-CHROMIUM ALLOYS

Drs. W.E. Dennis and F.D. Richardson of the Nuffield Research Group in Extraction Metallurgy at Imperial College have determined the thermodynamic activity of carbon in liquid iron-chromium alloys. Experiments were conducted to measure the equilibrium between carbon-containing melts and CO/CO₂ gas mixtures in the temperature range 1560° - 1760°C for alloy compositions up to 50 per cent Cr.

In the case of the binary C-Fe system the carbon activity is not markedly temperature dependent, and the deviations from ideal behavior are marked above 1.5 atomic per cent carbon. An increase in carbon content produces a marked increase in activity coefficient. In the ternary C-Fe-Cr system, the presence of Cr decreases the activity of C. The effect observed in the binary alloys of an increase in carbon activity with increase in carbon content is progressively decreased by Cr additions. Further, the rate at which Cr additions reduce the activity coefficient of carbon decreases with increasing Cr content. The results have been interpreted in terms of the theory of liquid structure and the Smith-Darken solution law based on statistical treatment of a simple model.

The results also establish the fact that the stable oxide of Cr in such systems is Cr₂O₃ rather than CrO as previously assumed by others. A set of working curves has been derived which should be of practical value in reducing Cr losses during decarburization in the operation of refining alloy steels and of producing low-carbon ferro-chromium.

Details of this work are given in Technical Report ONRL-2-53, available from the Technical Publications Office, Code 250, Washington 25, D.C.

PHYSIOLOGY OF RECEPTORS AND NERVE ENDINGS

A "Symposium on the Physiology and Pharmacology of Receptors and Nerve Endings" took place at the opening of the new physiology and pharmacology laboratories of the Kungl. Veterinärhögskolan, Stockholm, on December 5 and 6, 1952. The Symposium was under the chairmanship of Professors C.G. Schmiterlöw and Y. Zotterman of the Pharmacology and Physiology Departments, respectively. Thirty-one papers were presented by European scientists, and one report was given by an American. A few of the contributions are discussed briefly below.

Professor E.D. Adrian of Cambridge discussed some of his recent experiments on the sense of smell. Olfactory stimuli result in responses in the olfactory lobes, and different chemicals give electrical responses that are differently localized in these lobes. For example, acetone gives strong responses at the front of the olfactory lobes while amyl acetate gives strong responses at the back of the lobes. In general, substances that are soluble in water have a low response threshold at the front of the olfactory lobes, while substances soluble in lipoids have a low threshold at the back. It was found possible under certain conditions to record simultaneously the different responses to various stimuli from intermediate positions in the lobes. The results seem to show that the kind of smell that is experienced is correlated with the place and pattern of response.

Professor Alexander Forbes of Harvard reported some experiments by himself and Miss S. Burleigh. Burleigh and Forbes were concerned with the question: What happens in the electrical response of the whole eye when light of one wave length is instantaneously substituted for light of another wave length, particularly when the stimulating effects of both wave lengths are made equal? With such a change in stimulus the electrical record shows an off-effect due to the first stimulus and an on-effect due to the second. The on- and off-effects do not occur when light of the same wave length is substituted for itself; instead the electrical response is a smooth wave. These results indicate that different colors set up responses in relatively independent neural color pathways.

Dr. W.A.H. Rushton of Cambridge described a method designed to measure visual purple in the living eye. Light directed into the eye is absorbed by the visual purple in the receptors, reflected from the back surface of the eye, and absorbed again by the visual purple. The amount re-emerging is compared with a standard source. Under appropriate

conditions, the measured amount transmitted was established as that which remains after absorption by the visual purple. This method is new and in a preliminary stage of investigation, but its use seems to indicate that visual purple absorption in the rabbit eye is about 30 to 40 per cent.

" " Drs. B. Andersson and S. Larsson of the Veterinärhögskolan, Stockholm, reported on their experiments upon goats, each with a duct in its head extending into the brain. With this arrangement it was possible to inject very small amounts (e.g., 2 drops) of slightly hypertonic NaCl solution into the midbrain. The effect on the goat was shown in moving pictures. Excessive thirst occurs almost immediately after the injection. One goat, weighing 35 kg., drank more than 9 liters of water within a half-hour. The increased thirst lasts for about an hour after the injection.

ELECTROPHYSIOLOGICAL STUDIES OF THE EAR AND EYE

At a meeting of the Physiological Society, 16-17 January, Drs. S. Hilali and I.C. Whitfield of the University of Birmingham presented data on how much sound energy is required to produce responses in the trapezoid body, an early relay station in the auditory pathways. Electrical records were obtained of the responses of single nervous units. It was found, in accordance with other research, that, for tones higher than 500 cps, a single unit responds only to a restricted range of frequency, and that different units have different ranges. A new finding concerned the action of units sensitive to frequencies below 500; such units do not show the sharp selectivity characteristic of units sensitive to higher frequencies. These data have an important bearing on the mechanism of reception of low tones.

Dr. L.C. Thomson (Institute of Ophthalmology, London) reported the results of an experiment designed to see whether nervous activity in an eye that has remained in the dark is different from the activity of an eye that has remained in light. Thomson presumed that interaction effects between nervous units would be more prevalent in the dark adapted eye. He explored, with a small point of light, the area on the retina within which illumination produced responses in a given single fiber of the optic nerve. In each position, the least light energy that would provide a minimum response was determined. Near the center of the field so mapped, the energy required to provoke a response is small; near the extremes of the field, it is large. The extent of the field is about 12 degrees in the dark adapted eye, and in Thomson's experiment the limits of the field did not change when the eye remained in light.

Thus, the hypothesis that differential nervous action takes place during dark adaptation and light adaptation is not supported.

RESEARCH AT THE GERIATRIC UNIT OF THE GENERAL HOSPITAL IN SUNDERLAND

About two and one-half years ago the Newcastle-on-Tyne Regional Board No. 10 established in Sunderland a hospital unit of 350 beds to care for patients in the upper age group. Dr. Oscar Olbrich was appointed Director of this new project. The previous experience of Dr. Olbrich was at The Royal Infirmary, Edinburgh, and its Biochemical Laboratory, and also with the Queensbury House, Hospital for the Aged.

Since taking on the duties of directing the Geriatric Unit, Dr. Olbrich has built up a staff of seven physicians with varied training and experience. This unit copes with six thousand cases per year, of which three thousand are admitted for hospital treatment as in-patients, fifteen hundred are seen at the out-patient clinic, and fifteen hundred at the after-care clinic.

It has taken him some time to accumulate the necessary large equipment for his work but he has to date obtained an electrocardiograph and fluoroscope, and has been using as special equipment a magnetic and also a photoelectric ballistocardiograph of the Dock type. He plans to construct a ballistocardiograph of the type devised by Nickerson and Curtis.

The investigations are currently directed at studies of the cerebral circulation, renal function, and cardiovascular system in these aged patients. So far only the ground work of the project has been completed; however, a few points of more basic importance are becoming clear:

(1) In studying the inulin clearance at low plasma concentration there is evidence of some small tubular re-absorption of inulin;

(2) When tubular function is partially blocked the urea clearance is greater than the inulin clearance;

(3) Studies on the constituents of replacement fluids used in fluid therapy are leading to the opinion that the customary ionic relationships could be changed to advantage;

(4) In the treatment of gangrene of the extremities the use of a proximal arterial injection of diodrast has been found to delimit the affected area enabling this area to be removed. It appears that this procedure reduces the necessity for amputation of the whole limb.

THE EFFECTS OF DAILY IRRADIATION BY FAST NEUTRONS

Drs. G.J. Neary, R.J. Munson, and R.H. Mole of the Radiobiological Research Unit, Medical Research Council, Atomic Energy Research Establishment, Harwell, have exposed C.B.A. mice to continuous total body, nearly pure, fast neutron irradiation for a period now approaching two years. Four groups of 100 mice each were subjected simultaneously to planned doses of radiation, the maximum dose being 8.3 rep daily. One hundred control mice were kept under identical conditions except for the irradiation. It was only in the mice receiving 8.3 rep of fast neutrons daily that biologic changes were marked. Among the changes noted was a decrease in fertility which was manifest as early as nine weeks. If the animals were removed from irradiation after this time, 50 per cent recovered their reproductive capacity, as measured by mating trials. If left exposed for twelve weeks, only one of eight animals recovered its mating ability. Weight loss in the 8.3 rep mice became fairly marked after eight weeks of irradiation. One hundred per cent of the animals exposed to 8.3 rep died before the 95th week while mortality in the control and three other irradiated groups of mice amounted to only 25 per cent in the 95-week period. There was no difference in incidence of tumor formation in the irradiated and control mice except in the case of lung adenomata that, for reasons unknown, had an incidence of 22 per cent in the mice receiving 8.3 rep daily, while in all other mice the incidence was only 9 per cent. Further details on this and other work in progress at the Radiobiological Research Unit may be found in Technical Report ONRL-7-53 available from the Technical Publications Office, Code 250, Office of Naval Research, Washington 25, D.C.

TECHNICAL REPORTS OF ONRL

The following reports have been forwarded to ONR, Washington, since the last issue of ESN. Copies may be obtained from the Technical Publications Office, Code 250, Office of Naval Research, Washington 25, D.C.

ONRL-113-52 "The Symposium on the Physiology and Pharmacology of Receptors and Nerve Endings at the Opening of the New Physiology and Pharmacology Laboratories, Kungl. Veterinarhögskolan, Stockholm" by C.H. Graham

- ONRL-133-52 "Symposium on the Physics of the High Atmosphere" by S.F. Singer
- ONRL-134-52 "Russian Conference on the Origin of the Earth and Planets" by S.F. Singer
- ONRL-137-52 "Research in the Department of Technical Physics of the Technical Institute in Braunschweig" by G.J. Szasz
- ONRL-138-52 "Physical Chemistry Research at the Technische Hochschule, Braunschweig" by G.J. Szasz
- ONRL-139-52 "The Properties and Reactions of Chlorine Dioxide" by G.J. Szasz
- ONRL-140-52 "Research in Physical-Organic Chemistry at Leiden University" by G.J. Szasz
- ONRL-1-53 "Underwater Television, Report II" by R.R. Weber
- ONRL-3-53 "Physics of Solids at Imperial College, London" by J.R. Reitz
- ONRL-4-53 "Nuclear Research Facilities and Cosmic Ray Experiments at Harwell" by J.K. Beling
- ONRL-5-53 "Some Programs in Scandinavian Psychological Laboratories" by C.H. Graham
- ONRL-6-53 "The Chemistry of Biological After-Effects of Ultraviolet and Ionizing Radiations" by J.L. Tullis
- ONRL-7-53 "Radiobiological Research Unit, Medical Research Council, Atomic Energy Research Establishment, Harwell" by J.L. Tullis
- ONRL-9-53 "Solid State Physics Research at Erlangen, Germany" by J.R. Reitz

PERSONAL NEWS ITEMS

Professor P.M.S. Blackett has accepted the position of Chairman of the Department of Physics at Imperial College, University of London, effective November 1953. The position has been recently vacated by Sir George Thompson who was elected Master of Corpus Christi College, Cambridge.

Professor Blackett, a Nobel Prize Winner in the field of cosmic rays, has been directing cosmic-ray research at the University of Manchester. He has also been responsible for setting up the large radioastronomy program at Manchester and, more recently, a program in astronomy. It is expected that some of the cosmic ray physicists will transfer to Imperial College with him.

Imperial College, which is the largest scientific school in England, has figured prominently in recent months in discussions about the establishment of an Institute of Technology in the United Kingdom

Dr. H.F. Willis has been elected to succeed Mr. R.W. Cheshire as Superintendent of the Admiralty Research Laboratory, Teddington, England. Mr. Cheshire retired on January 31, 1953.

FORTHCOMING EVENTS

Symposium on Automatic Digital Computers

The National Physical Laboratory, Teddington, England, will hold a Symposium in London from 25 to 28 March, 1953. The Symposium will cover Design Principles, Utilization, Circuits and Components, and Servicing and Checking in the Light of Operational Experience of Digital Computing Machines, Medium-sized Digital Machines, and Brief Reports on European Machines. Further information can be obtained from Dr. E.T. Goodwin, Superintendent, Mathematics Division, National Physical Laboratory, Teddington, England.

Conference on the Physics of Ionized Gases

A Conference on the Physics of Ionized Gases will be held in the Physics Department, University College, Gower Street, London, W.C. 1, on March 23-25, 1953. It is being organized by Professor H.S.W. Massey, Chairman of the Department.

The program is intended to include: (1) present day techniques for studying ionized gases (microwave, optical, and mass spectrometer techniques); (2) recombination and diffusion (with special reference to the upper atmosphere); (3) positive and negative ions (including applications to meteor ionization and the ionosphere); (4) neutral atoms and molecules (including considerations of surface phenomena).

Symposia on Molecular Structure at the Sorbonne

The following meetings will be held in France, at the University of Paris (Sorbonne) in the summer of 1953.

24 - 26 June: A Colloquium sponsored by the Rockefeller Foundation and organized by the French National Bureau of Scientific Research (CNRS) on: "Water molecules in crystals and Solids studied by electromagnetic waves (from X-rays to wave lengths in the radiofrequency range)"
Active participation restricted to 20 invited persons. Secretary: Dr. A. Kastler, Laboratoire de Physique, ENS, 24 Rue Lhomond, Paris 5^e.

29 June - 3 July:

General International Meeting on Molecular Spectroscopy
(from X-rays to wave lengths in radio-frequency range)
Secretary: Dr. J. Lecomte, Laboratoire des Recherches Physique, Sorbonne, 1 Rue Victor Cousin, Paris 5^e.

6 - 10 July:

Symposium organized by the Societe Francaise de Chimie Physique, on "Recent Advances in Studies of Molecular Structure".
Secretary: Dr. M. Magat, Laboratoire de Chimie Physique, 11 Rue Pierre Curie, Paris 5^e.

Spring Meeting of the Physical Society, 1953

The Spring Meeting of the British Physical Society will be held in the Department of Physics, Leeds University, on Monday, Tuesday, and Wednesday, March 30, 31, and April 1, 1953. The program will be divided into three sessions covering various aspects of solid state physics: analysis of magnetization curves, band theory of metals, and ferroelectricity and luminescence.

Prepared by the Scientific Staff
Submitted by Dr. S.R. Aspinall
Deputy Scientific Director

Philip D. Lohmann

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Assistant Naval Attache for Research

