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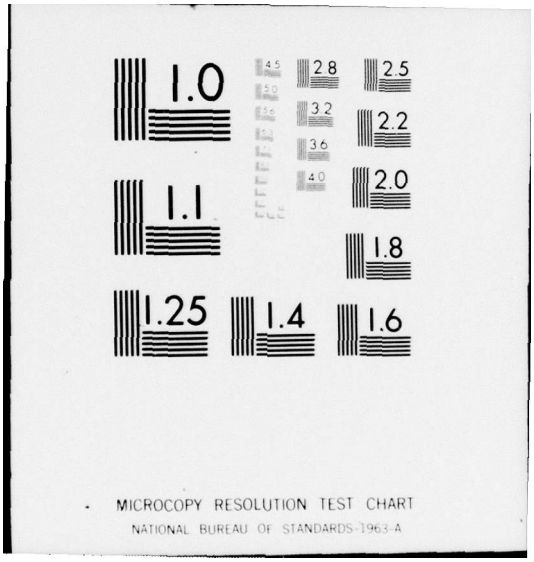
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J. R. Reitz
S. R. Aspinall

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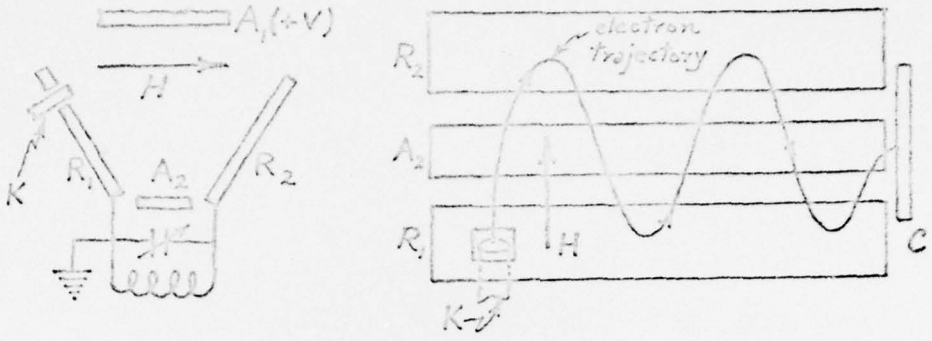
THE STROPHOTRON: AN ELECTRON TUBE OF MULTI-REFLECTION TYPE

Professor H. Alfvén and Mr. D. Romell, Royal Institute of Technology, Stockholm, have developed a new type of vacuum tube oscillator called the strophotron from a Greek word meaning "to turn hither and thither". The operation of the tube, which is similar in some respects to that of a Barkhausen oscillator, is as follows: electrons interacting with the high-frequency electric field oscillate in an electrostatic field, and simultaneously, are given a controlled drift velocity in a direction perpendicular to the oscillatory motion by means of crossed electric and magnetic fields or inhomogeneous magnetic fields, the drift velocity serving to transport the electrons out of the interaction space to a collector electrode. The advantage of this tube when used as an oscillator is that it operates at high efficiency (about 30%) in the frequency range of 100 to 10,000 megacycles/sec, and this frequency can be easily controlled by varying the electrostatic field, i.e., by varying the voltage V (see Fig. 1).

It should be noted that the operation of the strophotron is entirely different from devices working on the magnetron principle. In such devices the active components of the high-frequency electric field



View from side View from above

Fig. 1. Schematic diagram of the strophotron. R_1, R_2 = reflectors, A_1, A_2 = anodes, K = cathode, C = collector electrode, H = magnetic field, V = electrostatic potential of A_1.

and the components of electronic motion are perpendicular to the magnetic field. In magnetrons the frequency of electron rotation or oscillation, which is determined by the magnetic field, is identical with or closely related to the frequency of operation of the device as a whole. In strophotrons, on the other hand, the active component of the high-frequency electric field and electronic motion associated therewith are essentially parallel to the magnetic field. The magnitude of the magnetic field, which has no effect whatever on the frequency of operation, influences the drift velocity, v, of electrons in that $v = E/H$; here E is the component of the electric field perpendicular to the magnetic field and H is the magnitude to the magnetic field.

Since the electron oscillation frequency is governed solely by the electrostatic potential of the various anodes, the strophotron offers convenient means for electrical tuning, frequency modulation, and automatic frequency control. In the non-oscillating condition of the tube the electrons are more or less evenly distributed throughout the "electron sheet", which is defined as the region containing the electron trajectories; at any instant, the number of electrons moving in one direction along the direction of the magnetic field will equal the number moving in the opposite direction. The action of the radio-frequency field existing under operating conditions is two-fold; firstly, there is a redistribution of electron velocities so that at a given instant there will be a surplus of electrons moving in the direction of the magnetic field, and one-half cycle later in the opposite direction. Secondly, the electron beam having thus been bunched will give off energy to the radio-frequency field, this energy of course being supplied by the electrostatic field.

The novel and useful feature of strophotrons which distinguish them from other types of oscillator tubes derives mainly from the fact that the electrons are allowed to carry out a number of oscillations (of the order of 10) in the interaction space, and the electron drift velocity is in a direction perpendicular to the oscillatory motion. In this way the electrons are able to give off most of their energy to the radio-frequency field before being carried away. This circumvents the disadvantages inherent in multi-reflection tubes in which the space charge is not carried away in an orderly fashion. In this latter case it is quite likely that electrons will hit one of the electrodes and be lost after having given off only a fraction of their energy to the radio-frequency field.

THE REACTION $Be^7(n,p)Li^7$

The proton-induced reaction $Li^7(p,n)Be^7$ has been known for a long time and is a common source of monoenergetic neutrons. The threshold for the reaction is 1.88 Mev. The inverse reaction $Be^7(n,p)Li^7$ should therefore proceed with slow neutrons with a cross section in accordance with statistical mechanics and in particular with the principle of detailed balancing.

R. Hanna (A.E.R.E., Harwell) has completed a long and careful investigation of this latter reaction using a sample of Be^7 from the Harwell cyclotron. The Be^7 was produced in the graphite beam scrapers of the cyclotron according to the reaction $C^{12}(p,\alpha pn)Be^7$. A sample of weight 3×10^{-9} gm was obtained, which had the well-known half life of 53 days. This sample was mounted on a platinum disc situated in a pulse ionization chamber which in turn was placed in the slow neutron flux of the reactor BEPO. A flux of 5×10^5 slow neutrons/cm^2sec yielded a counting rate under this geometry of approximately 80 counts per minute. From this Hanna calculated a cross section for the reaction $Be^7(n,p)Li^7$ of 53,000 barns.

Several checks and tests were made to make sure that the pulses observed in the ionization chamber were actually due to protons from the reaction being investigated. One check made was to observe that the number of pulses per unit flux actually decreased with an approximately fifty-day half life. The most likely contamination which might give pulses of the observed size and

frequency is boron undergoing the reaction $B^{10}(n,\alpha)Li^7$. The energy given to the alpha particles in this reaction is 1.46 Mev compared to 1.44 Mev energy given to the protons in the reaction being investigated. Hanna distinguished between these two possibilities by varying the pressure of the gas in the ionization chamber. Since the range of the alpha particles would be much less than that of the protons, the pulse height should start to drop much sooner as the pressure is reduced if the pulses are due to protons. The variation with pressure was indeed found to correspond to that expected from the protons.

Hanna was also able to measure the cross section of the $Be^7(p,n)Li^7$ reaction by observing the destruction of the Be^7 in a high slow neutron flux. This experiment, which is considerably more difficult to do, yielded a result of 45,000 barns, with a somewhat larger uncertainty than in the first experiment.

The principle of detailed balancing when applied to the two inverse reactions mentioned here gives a relation between the cross sections of the two processes and the total angular momenta of the Li^7 and Be^7 nuclei. The J-value of Li^7 is known to be $^3/_2$ but that of Be^7 is not known. One could hope to determine this from the ratio of the two cross sections but unfortunately the cross section of the reaction $Li^7(p,n)Be^7$ is not known right at threshold where it is needed for this calculation. The latter cross section has been determined using the Van der Graaf at Harwell down to an energy 4 kev above threshold. If one extrapolates the trend in cross section to threshold

energy, the value obtained yields a J for Be^7 of $\frac{1}{2}$. However, it must be emphasized that this is an extrapolation, and the behavior of the cross section curve needs to be checked in this region.

A NEUTRON SCINTILLATION DETECTOR CONTAINING BORON

In the instrumentation of time-of-flight neutron spectrometers it is very desirable to have a detector which has the following characteristics: (1) small dimensions in order to reduce the indeterminancy of the flight path from source to detector, (2) fast response time in order to reduce the indeterminancy of the flight time, (3) a response sensitivity which varies as slowly as possible with neutron energy and (4) preferential sensitivity to neutrons versus the general gamma ray background. A scintillation detector containing boron might be expected to exhibit at least the first three characteristics.

J. Kirkbride (A.E.R.E., Harwell) has continued work on the development of scintillation materials containing boron (Nature 171, 564 (1953)). He has further investigated borazole, $B_3N_3H_6$, which is a compound having the same ring structure as benzene, with boron and nitrogen atoms alternately around the ring. Mixtures of varying proportions of borazole and benzene have been used as scintillators with the result that the light output of the mixture is directly proportional to the molar concentration of benzene present. He concludes that the borazole does not itself scintillate but on the other hand it does not quench the processes of exciton transfer in the benzene. The light absorption curves of the two liquids look approximately as shown in the figure. Thus there is very little absorption of the benzene radiation in the

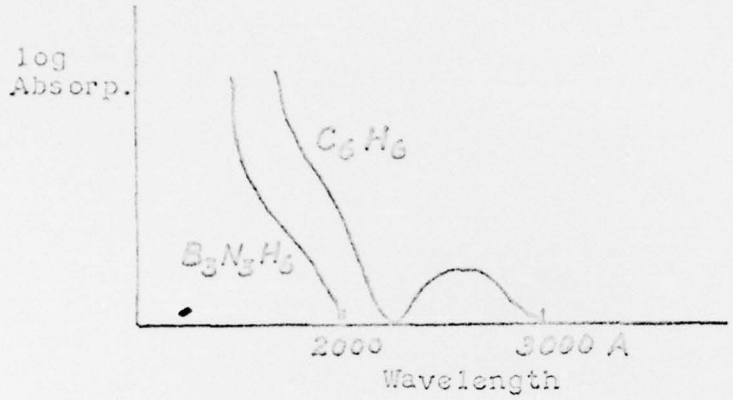


Fig. 1. Light absorption in benzene and borazole.

borazole. The response time of the scintillator is less than 10^{-8} sec. The boiling point of the borazole is 55°C.

Another material which has been investigated by Kirkbride is boron nitride. The crystal structure of this material is like that of graphite, that is, hexagonal, with the nitrogen and boron atoms in alternate positions. Unfortunately it has been found possible to prepare only small crystals of this substance. Its properties and usefulness are then similar to those of ZnS, which means that it is of little use in a high velocity neutron spectrometer. There may, however, be other uses in experiments where a neutron detector in the form of a thin foil would be desirable.

IMPURITY-VACANCY COMPLEXES IN ALKALI HALIDES

Mr. F. Bassani and Professor F. G. Fumi (University of Milan), using the Born-Mayer model of an ionic crystal, have recently calculated the association energies of a number of divalent impurity ions and positive-ion vacancies in both KCl and NaCl lattices. The calculational procedure was essentially the same as that used by Reitz and Gammel (J. Chem. Phys. 19, 894 (1951)) to determine the association energy of Cd^{++} and a positive-ion vacancy in NaCl. The results of Bassani and Fumi's investigation are summarized below.

Table I. Association energies (in ev) of divalent impurity - vacancy complexes in alkali-halide crystals.

Type of lattice	Divalent impurity		
	Cd^{++}	Ca^{++}	Sr^{++}
NaCl	0.46	0.47	0.64
KCl	0.11	0.12	0.22

Thus the results show that the association energy increases with the ionic radius of the impurity ion, and is appreciably smaller in KCl than in NaCl.

The theoretical work fails to confirm the experimentally-observed difference in association energies for the Cd^{++}-vacancy complex and the Ca^{++}-vacancy complex, i.e., 0.3 to 0.35 ev for the case

of Cd (Etzel and Maurer, J. Chem. Phys. 18, 1003 (1950)) and < 0.08 ev for the case of Ca (C. Bean, Thesis, Univ. of Illinois). Bassani and Fumi suggest that the limits of existence of solid solutions between alkali halides and added impurities should be more extensively studied in order to determine that the impurities are uniformly distributed in the sample and occupy substitutional positions during experimental determinations of the association energy.

ELECTRICAL CONDUCTIVITY OF BORON TRIFLUORIDE COMPLEXES

The remarkably high electrical conductivity of a number of boron trifluoride complexes in the liquid state has been investigated by Dr. N. N. Greenwood (Harwell, at present at the University of Nottingham) and Dr. R. L. Martin (Cambridge). The conductivity measurements were made on highly purified substances with rigorous exclusion of moisture and other impurities. The results were summarized in the last of a series of papers dealing with this work (JCS. 1427 (1953)). Despite their low melting points the boron trifluoride complexes have conductivities almost of the order characteristic of molten salts. The validity of the laws of electrolysis in the melt and the large increase in conductivity on melting suggest that the mechanism of conduction in these substances is ionic rather than electronic. The high purity of the samples, the shape of the conductivity-composition isotherms (cf. loc. cit.), and the observation of definite decomposition potentials all indicate that the ionic conductivity is due to self-ionization of the melt. The mode of ionization suggested by Dr. Greenwood for a number of these complexes is given in the table below, together with the degree of dissociation in each case; it will be noted that this latter quantity varies over a very wide range, i.e., about a factor of 200. The nature

of the ions formed in these self-dissociation processes was deduced from electrolysis experiments.

Table I.

Ionic Dissociation of Molten Complexes

Compound	Mode of Ionization		Degree of Ionic Dissociation in per cent
$BF_3.H_2O$	H^+	BF_3OH^-	10
$BF_3.2H_2O$	H_3O^+	BF_3OH^-	20
$BF_3.MeOH$	H^+	BF_3OMe^-	2
$BF_3.2MeOH$	$MeOH_2^+$	BF_3OMe^-	7
$BF_3.2PrOH$*	$PrOH_2^+$	BF_3OPr^-	3
$BF_3.HOAc$	H^+	$(BF_3.MeCO_2)^-$	5
$BF_3.MeOAc$*	H^+	$(BF_3.MeCO_2CH_2)^-$ and	0.2
	$MeCO^+$	BF_3OMe^-	
$BF_3.EtOAc$*	H^+	$(BF_3.MeCO_2C_2H_4)^-$ and	0.09
	$MeCO^+$	BF_3OEt^-	
$BF_3.Et_2O$	Et^+	BF_3OEt^-	0.07
	and possibly some		
	H^+	$(BF_3.EtCC_2H_4)^-$	

* preliminary analyses only

The postulated self-ionization processes readily explain the fact that the 1:2 complexes are more stable than the corresponding 1:1 compounds; here 1:2 and 1:1 represent the ratio of BF_3 to the donor. The 1:1 compounds are analogous to the unstable anhydrous protonic acids such as H_2CO_3, free HBF_4, etc. In the case of the 1:2 complexes the second donor molecule solvates the proton yielding stable oxonium type ions. This second donor molecule could also be of a different species and this leads to the possibility of 1:1:1 complexes, such as the stabilization of the hypothetical fluoboric acid, $BF_3.HF$, by the addition of a molecule of water yielding $H_3O^+BF_4^-$, or by a molecule of ammonia yielding $NH_4^+BF_4^-$.

These coordination compounds were reviewed by Dr. Greenwood at the meeting on Coordination Chemistry in Copenhagen in August 1953 and will appear in expanded form in the quarterly review of the Chemical Society of London.

USE OF PIPERAZINE AGAINST INTESTINAL NEMATODES

Dr. O. D. Standen, of the Wellcome Laboratories of Tropical Medicine, working in collaboration with several doctors at Guy's Hospital, London, has found the well-known chemical piperazine to be exceptionally effective against the pinworm of man, *Enterobius vermicularis*. The drug is given orally and has a wide margin of safety. In the course of conducting the clinical tests it was discovered that approximately 60 per cent of the children admitted to the pediatric service harbored this parasite. The drug has also been tried in a preliminary fashion against *Ascaris lumbricoides* and appears to show equal therapeutic effect against this worm.

A formal report of this research will appear in the medical literature shortly.

RETINAL ABSORPTION

Dr. Eric Denton of the Department of Physiology, Marischal College, Aberdeen, has been making new determinations of the per cent of light absorption in the dark adapted frog retina. The method is as follows.

A fresh retina is placed on a microscope slide. (It can be shown by photography that such a retina contains two kinds of rods; the conventional ones and "green" rods. About one in 10 of the population of rods is a "green" rod.) The fresh retina is photographed during the first moment of exposure to the bleaching light. Thereafter the bleaching light continues to shine until the rhodopsin is totally bleached, whereupon further photographs are made in the presence of the bleaching light into whose beam filters of varying density are interposed for successive photographs. The density value of the filter producing the photograph that matches the initial photograph (obtained before bleaching) gives the density change in rhodopsin during bleaching. It turns out that this value of density (about 0.7) is higher than those heretofore estimated from *in vitro* bleaching. This figure means that the average total absorption of rhodopsin is about 45 per cent, a much higher value than those estimated earlier. It now seems from the determinations of Denton (and those of Rushton, done at Cambridge on the intact rabbit eye) that previously-held ideas about the absorption characteristics of rhodopsin must be changed.

NUFFIELD RESEARCH UNIT ON PROBLEMS OF AGEING

In 1946, the Nuffield Foundation made a grant to the University of Cambridge for the establishment of a Nuffield Research Unit on Problems of Ageing, to be attached to the Psychological Laboratory. It was planned that the Unit make a broad study of ageing, with particular emphasis on the study of changes of skill in middle and old age, and with a view to applications in industry. The director of the Unit, since its beginning, has been Mr. A. T. Welford.

The Unit is currently engaged in several lines of research, one of which, by W. T. Singleton, concerns a device for measuring quantitatively the loss of skill accompanying old age. This device is herewith described.

A standard display contains four lights at the points of a square. Any single light may be illuminated by means of a complex electrical circuit. Illumination of lights in a matching display is controlled by the subject, who moves a joy stick in the direction indicated by the light of the standard display. When the correct movement is made in the matching display, the light on the standard display goes out and another one goes on. In a word, the subject must successively match the lights in the standard by means of his joy stick control. The problem is simple when the "North" of the standard display corresponds to the "North" of the matching display. It is not so simple when a reference light on the standard display indicates any one of the other three directional references. For example, when the reference light of the standard display signals that the "East" position on the matching display is now to be considered "North", a movement "South" on the standard display means that

the subject must move his joy stick to "West" on the matching pattern. When the reference on the matching pattern is oriented 270° or 90° from the reference position of the standard pattern and when appropriate adjustments have to be made for other directions with respect to the reference position, then performance deteriorates. With an increase in age, the deterioration is greatly accentuated.

TECHNICAL REPORTS OF ONRL

The following reports have been forwarded to ONR, Washington. Copies may be obtained by addressing requests to the Commanding Officer, Office of Naval Research Branch Office, Navy No. 100, c/o Fleet Post Office, New York, N. Y.

ONRL-99-53 "Nuclear Physics Research at the French Atomic Energy Establishment, Saclay" by S. F. Singer

ONRL-100-53 "X-ray Crystallography of Inorganic Compounds at the Cavendish Laboratory" by R. W. Mooney

ONRL-101-53 "Second Symposium on Gasdynamics of the Interstellar Clouds" by W. D. Hayes

ONRL-102-53 "Summer Meeting of the Pathological Society of Great Britain and Ireland" by J. L. Tullis

ONRL-103-53 "The Cosmic Ray Conference at Bagneres de Bigorre, 6-12 July 1953" by J. R. Richardson

ONRL-104-53 "The Crystal Structure of Rh_2B" by R. W. Mooney

ONRL-105-53 "The Cambridge Meeting of the Experimental Psychology Group" by C. H. Graham

ONRL-106-53 "Discussion on Recent Progress in the Study of Molecular Structures" by G. J. Szasz

ONRL-107-53 "International Meeting on Molecular Spectroscopy" by G. J. Szasz

ONRL-108-53 "Conference on the Theory of the Plastic Deformation of Metals" by E. Epremian and J. R. Reitz

ONRL-109-53 "Solid State Physics in Darmstadt" by J. R. Reitz

ONRL-110-53 "The Eleventh International Congress of Psychotechnic, Paris" by C. H. Graham

ONRL-111-53 "Some Researches on Visual Processes in Scotland, Italy and France" by C. H. Graham

ONRL-113-53 "Physiological Research in the Netherlands and Belgium" by J. L. Nickerson

ONRL-114-53 "Heavy Water Reactor Conference, Kjeller, Norway, 11-13 August 1953" by J. R. Richardson

ONRL-115-53 "Physiological Society Meetings at Cambridge" by J. L. Nickerson

ONRL-116-53	"UK-USA Conference on Jet Noise, Southampton University, 29-30 June 1953" by M. E. Bell
ONRL-117-53	"Computers at the Federal Institute of Technology, Zurich" by R. R. Weber
ONRL-118-53	"Interference Microscopes" by W. L. Hyde
ONRL-119-53	"The Sequelae of Thorotrast Injections for Diagnostic Radiography in Human Beings and Experimental Animals" by J. L. Tullis
ONRL-120-53	"Some Psychological Programs in Switzerland, France and Italy" by C. H. Graham

NEW JOURNAL ON DEEP SEA RESEARCH

The first issue of the new international quarterly, "Deep Sea Research", will appear shortly; it is published by Pergamon Press Ltd., London. The editors are L. Fage (Paris), C. D. Ovey (Cambridge) and Mary Sears (Woods Hole, Mass.), and the Editorial Advisory Board includes H. Urey (Chicago) and M. Ewing (New York).

This journal is the official organ of the Joint Commission on Oceanography of the International Council of Scientific Unions. The main theme of interest will be investigations of the deep-sea floor, including work on various physical and biological problems relevant to it.

FORTHCOMING EVENTS

Nuclear Physics Conference at Glasgow

A conference on nuclear physics, under the auspices of the International Union of Pure and Applied Physics, will be held at Glasgow University during 13-17 July 1954. It is proposed that the following topics will be discussed: two-body interaction, disintegration experiments, nuclear spectroscopy, the shell model, mesons from high-energy machines, and heavy mesons. Further information about the conference can be obtained from Dr. K. G. McNeill, Secretary, 1954 Physics Conference, Department of Natural Philosophy, The University, Glasgow, W. 2. It is requested that American scientists who plan to attend the conference notify Dr. McNeill by 1 December 1953.

Faraday Society Discussion Meeting at Birmingham

A General Discussion of the Faraday Society on "The Study of Fast Reactions" will take place at the University of Birmingham on 7-9 April 1954. The fast reactions to be covered in this Discussion are defined as having a half-life of less than a few seconds and thus being inaccessible to measurement by conventional methods. Studies concerned exclusively with electrode processes and explosions are excluded from the program in order to keep the subject matter within a convenient range.

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

T. S. CREASOR
Captain, U.S.N.
Assistant Naval Attache for Research