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Argonne National Laboratory

PHYSICS DIVISION SUMMARY REPORT

January—March 1968

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Physics
AEC Research and
Development Report

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

PHYSICS DIVISION SUMMARY REPORT

January—March 1968

Lowell M. Bollinger, Division Director

Preceding Summary Reports:

ANL-7355, April-June 1967
ANL-7384, July-September 1967
ANL-7405, October-December 1967

FOREWORD

The Physics Summary is issued several times per year for the information of the members of the Division and a limited number of other persons interested in the progress of the work. It includes short reports on highlights of the current research, abstracts or short summaries of oral presentations at meetings, abstracts of papers recently accepted for publication, and publication notices of papers appearing in recent journals and books. Many of these reports cover work still in progress; the results and data they present are therefore preliminary, tentative, and often incomplete.

The research presented in any one issue of the Summary is only a small random sample of the work of the Physics Division. For a comprehensive overview, the reader is referred to the ANL Physics Division Annual Review issued each summer, the most recent being Argonne National Laboratory Report ANL-7354, which reports research in the year ending 31 March 1967.

The issuance of these reports is not intended to constitute publication in any sense of the word. Final results will be submitted for publication in regular professional journals or, in special cases, presented in ANL Topical Reports.

TABLE OF CONTENTS

I. RESEARCH HIGHLIGHTS

These research highlights are Physics Division contributions to the Physical Research Monthly Report which the Laboratory Director's Office sends to the Division of Research of the U. S. Atomic Energy Commission. They report interesting work that is currently in progress or that has just been completed.

THE ARGONNE SYMPOSIUM ON THE NUCLEAR MANY-BODY PROBLEM, 27—28 DECEMBER 1967

Murray Peshkin

The Symposium on the Nuclear Many-Body Problem, held at Argonne during the Christmas holiday, was planned as a working man's conference. Its purpose was to enable active workers in the nuclear many-body field to obtain detailed information about the approximations currently being made by other workers in the field, to learn why those approximations are made, and to see what effect various approximations have on the outcome of numerical calculations. Such a symposium appeared to be timely; many of the research programs are still in the early stages of large-scale numerical calculations so that precise information about the experiences of others is very valuable.

The limited purpose of the symposium made its organization simple—though unusual in one respect. It was obviously necessary to keep the group small for the benefit of useful discussion. Nevertheless, the organizers of the symposium (Drs. B. D. Day, M. H. Macfarlane, and M. Peshkin assisted by several outside participants, especially Dr. M. Baranger) were able to invite representatives of all the relevant North American programs that they knew about. In addition to the 26 visitors from 17 universities, there were 17 Argonne participants. The

formal presentations were limited to eight papers distributed over two full days, the invited speakers being M. Baranger of Carnegie-Mellon Institute, J. W. Clark of Washington University, St. Louis, F. Coester of Argonne, S. Kahana of Brookhaven, T. T. S. Kuo of Princeton, C. M. Shakin of MIT, D. Sprung of McMaster University, and L. Wilets of the University of Washington, Seattle.

The unusual feature was the effort to have the talks presented by the men who were closest to the details of the calculations, even when this meant that the speaker was not necessarily the participant most appropriate as the general representative of a research program.

The symposium proceeded as expected. The speakers addressed themselves to the wanted details, and were questioned intensively by the conferees both during and after their talks. The unsatisfactory aspects of the various procedures formed the principal topic of conversation, both on and off the floor. These exposures proved very valuable to the Argonne group, and presumably also to the other participants.

An attempt to summarize the present position would have been inappropriate to the principal business of the symposium and no such summary was presented. It was the clear tenor of most of the talks that the nuclear many-body problem is not substantially solved. There is much information about the numerical consequences of various assumed nucleon-nucleon forces for calculations with certain approximations. Mostly those are calculations in which approximations are tested by evaluating some appealing correction terms, but in which no systematic procedure for estimating errors has yet emerged. There are also several schemes in which a systematic approximation procedure is attempted. Those have not reached the stage of attempting seriously to compare force laws with nuclear data; the present emphasis is on the estimation of errors with a force law having the general behavior of the probable real ones.

SUPERCONDUCTING INTERNAL-CONVERSION-ELECTRON SPECTROMETER

S. B. Burson

Intensive research has focused upon the spectrum of gamma rays emitted by the nucleus as a result of thermal neutron capture. High-precision Compton and diffraction gamma-ray spectrometers and, more recently, germanium-diode detectors have yielded a wealth of information concerning the energies of transitions and of many of the excited states of the product nucleus. However, these data rarely yield unambiguous evidence about the spins and parities of the levels. In an effort to reduce the extent of these ambiguities, there have been a number of attempts to measure the internal-conversion coefficients of some of the transitions—but most of the successful experiments have been on nuclides with extremely high capture cross sections. The new conversion-electron spectrometer being constructed at Argonne will use an external beam from the reactor CP-5. The beam experiment (in contrast to a target-in-pile experiment) has the advantage that gamma-ray and conversion-electron spectra can be measured simultaneously and with the same sample. Moreover, with suitable instrumentation, γ-e^-, γ-γ, and other coincidence experiments are possible.

The principle of operation of the system is shown schematically in Fig. 1. A collimated beam of thermal neutrons from the reactor enters an evacuated target chamber (8 in. in diameter and 3 in. high) and impinges upon a thin target located at the center of the chamber. The target is mounted on a carrier by which it is moved along a path intersecting the beam at right angles. The carrier passes through a vacuum lock which allows the insertion or removal of samples from the chamber without disturbing the vacuum. The detectors are mounted on a vertical line through the intersection of the beam and the path of the target.

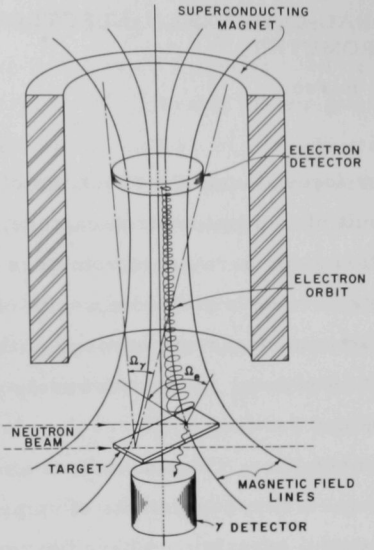

Fig. 1. Arrangement of the superconducting solenoidal magnet, the target, and the Si(Li) and Ge(Li) detectors. With this system, the Si(Li) electron detector can be remote enough from the target that the γ-ray background is significantly attenuated while at the same time the condensing action of the magnetic field ensures the collection of electrons emitted into a large solid angle.

The gamma-ray detector, a 7-cm^3 Ge(Li) diode, is housed in an independent vacuum system. It is inserted into the target chamber through a sleeve sealed with O rings so that its distance below the target can be adjusted. From a hole through the center of the top cover of the target chamber, an evacuated tube (1.5 in. in diameter) extends upward a distance of 50 in., passing completely through the liquid helium cryostat in which the superconducting magnet is housed. The electron detector, a Si(Li) diode 0.75 in. in diameter and 2 mm thick, is mounted on the end of a cold finger suspended from the top of the through tube. The distance from target to detector can be adjusted by moving the cold finger up or down in the tube.

The magnet measures 2 in. inside diameter by 10 in. long and is situated immediately above the target chamber. Its central field is about 2×10^4 gauss. Conversion electrons having a velocity component upward along this field as they leave the target describe helical paths up the tube until they strike the detector approximately 10 in. above the target. This focusing action in effect enhances the solid angle of the

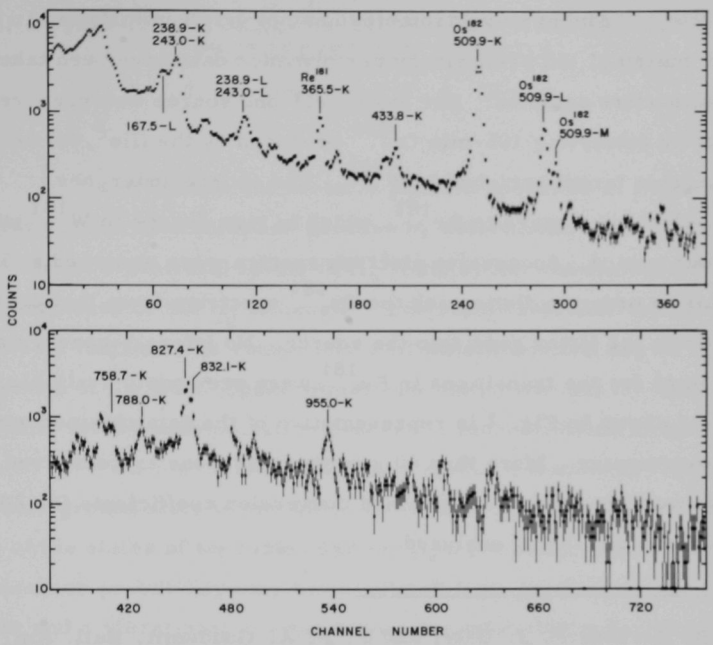

Fig. 2. Internal-conversion spectrum of Os^{181}, observed 30 min after chemical separation from the W^{182} target. For simplicity, the lines of only eight of the transitions have been indicated.

electron detector approximately 50 fold, but the inverse-square law still reduces the gamma-ray flux at the detector. The electron spectrum obtained is thus virtually free of gamma-ray background.

The electron detector currently in use has a resolution width of 6 keV at the 975-keV line of Bi^{207}, a value competitive with that of beta-ray spectrometers of conventional design. In addition, the Si(Li) detector has the advantage of making integral rather than differential measurements—i.e., all electrons striking the detector are analyzed for energy. The magnetic lens not only enhances the electron intensity relative to the gamma background but also affords an acceptance angle comparable to that of the best conventional spectrometers.

The new spectrometer has not yet been installed in the reactor building, but preliminary performance data have been taken with radioactive samples. For example,[1] one source was prepared by chemically extracting 105-min Os^{181} produced by the (He^3,4n) reaction on a tungsten target enriched in W^{182}. The source undergoes orbital-electron capture to Re^{181}, which in turn decays to W^{181} with a 20-hour period. Successive electron spectra were observed at 30-min intervals in order to distinguish the Os^{181} spectrum from that of the daughter as the latter grew into the source. No internal-conversion coefficients for the transitions in Re^{181} were previously available. The spectrum shown in Fig. 2 is representative of the data obtained with the new spectrometer. More than 60 gamma transitions are observed, and of these we have already determined conversion coefficients for 20. The data are still being analyzed.

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[1] S. B. Burson, P. J. Daly, and P. F. A. Goudsmit, Bull. Am. Phys. Soc. 13, 673 (April 1968).

ANALYSIS OF AUTOIONIZATION IN H_2 BY MEASUREMENT OF PHOTOELECTRON ENERGIES

J. Berkowitz and W. A. Chupka

An instrument recently put into operation at Argonne tests the theory of the autoionization process by determining the relative populations of vibrational levels in H_2^+ ions by autoionization and by direct ionization of the H_2 molecule. The vibrational distribution arising from direct ionization is reasonably well understood and can be computed with the aid of the Born-Oppenheimer approximation; but the transition probability for the autoionization process is more difficult to calculate.

When a diatomic molecule makes a transition from its electronic ground state to one of its excited electronic states or directly to one of the states of the molecular ion (i.e., in direct ionization), the transition probability may be calculated from an electronic transition moment and a vibrational overlap term—the latter being referred to as a Franck-Condon factor. In such calculations it is frequently assumed that the electronic and nuclear motions of the molecular system may be treated separately, a procedure known as the Born-Oppenheimer approximation. Calculations of this type have been performed for the transition from H_2 to H_2^+ in its $^2\Sigma_g^+$ electronic ground state but in various states of vibrational excitation, i.e., for

$$H_2(^1\Sigma_g^+,\ v'' = 0) + h\nu \rightarrow H_2^+(^2\Sigma_g^+,\ v' = 0, \cdots, 6).$$

The Franck-Condon factors (the probabilities of producing the ion in these vibrational states) were found to be as shown in the table.

v	0	1	2	3	4	5	6
Relative transition probability	0.0922	0.1751	0.1959	0.1700	0.1275	0.0874	0.0566

For another process that can occur in the case of H_2, however, the Born-Oppenheimer separation is not a sufficiently good approximation; the transition probability includes terms involving a mixture of nuclear and electronic motions, and some of these cannot be neglected. One consequence of these cross terms is that there is an additional mechanism for ionization, in which the H_2 molecule absorbs sufficient total energy to ionize but this energy is shared with its electronic and nuclear motions so the most loosely bound electron has too little energy to be ejected immediately. The subsequent relaxation of vibrational excitation then can result in ejection of the electron, a process called autoionization. Calculation of the transition probability for this process has been attempted only recently.

One experimental test of the theory is to determine the probability of autoionizing H_2 to form $H_2^+ (^2\Sigma_g^+)$ in various states of vibrational excitation. Our new apparatus for this purpose consists of a vacuum-ultraviolet monochromator, a light source generating the Hopfield continuum of helium, and a retarding-field energy analyzer to determine the energies of the ejected photoelectrons. The energy spectrum of the photoelectrons is measured in a selected wavelength band in which autoionization predominates. From the known photon energy, the ionization potential of H_2, and the photoelectron spectrum, one can deduce the distribution of H_2^+ in its various vibrational states. Another photoelectron spectrum is then taken in a wavelength band in which the photons have approximately the same energy but produce very little autoionization. The difference between these photoelectron spectra provides a measure of the H_2^+ vibrational population that is due predominantly to autoionization.

In preliminary experiments, it has been found that the autoionization peaks seen in the wavelength band at 778.8 ± 0.8 Å form H_2^+ in the v=2 level at least 15 times as abundantly as in the v=1 level,

and still less is formed in the v=0 level. A similar observation has been made with the autoionization at 784.0 ± 0.8 Å, where the H_2^+ is formed in the v=1 state at least 15 times as abundantly as in the v = 0. In both instances, production of photoelectrons with the lowest kinetic energy is clearly preferred. The autoionizing states are not yet well identified, however, so the "propensity rule" derived by Berry for autoionization in H_2 ($\Delta v=1$ transitions preferred) cannot be verified immediately.

II. REPORTS AT MEETINGS

The abstracts and summaries that follow are not necessarily identical to those submitted for the meeting. In some cases, the authors have corrected or expanded abstracts; and summaries of contributed papers commonly have been shortened.

Colloque International sur l'Interaction des Champs H. F. (Appliques ou Auto Engendres) Associes a un Champ Magnetique Statique avec un Plasma

L'Institut National des Sciences et Techniques Nucleaires et la Direction de la Physique, Saclay, France, 15—18 January 1968

FREQUENCY-SHIFTING METHOD OF EXCITING PLASMAS IN FUNDAMENTAL-MODE RESONANT CAVITIES

Albert J. Hatch, S. L. Halverson,* and A. E. Froehlich

Session VII

This paper reports a new frequency-shifting method of exciting plasmas in fundamental modes of resonant cavities. The cylindrical cavity used is 33 cm in diameter and 42 cm long, has a Pyrex vacuum liner, and exhibits a Q of ~4000. Its perforated wall has an optical transmission of $\frac{2}{3}$. Plasmas are excited by the TE_{111} and the TM_{010} modes in the nominal frequency range 625—750 MHz and approximate pressure range 10—35 mTorr by a continuously tunable power source delivering ~25 W. Photographs (Fig. 3) show that the spatial distribution of plasma corresponds closely to that of the electric field. An automatic impedance plotter and an impedance-matching network enable the operator to shift the excitation frequency while keeping an appropriate impedance relation between power source and cavity, thereby maintaining the plasma. Frequency shifts as large as +10% of the resonant frequency of the empty

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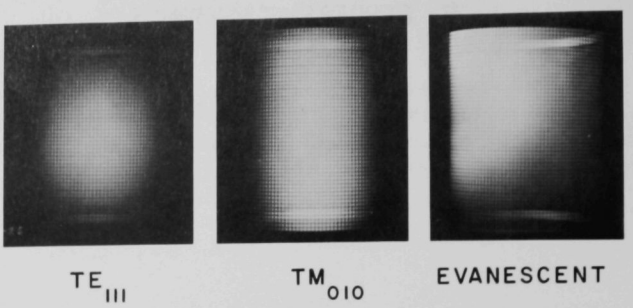

Fig. 3. Luminosity of a plasma in the semitransparent cylindrical cavity excited in the three modes indicated. The pressure was ~15 mTorr in air. In each case the luminosity pattern corresponds closely to the electric field distribution. The small separate "glows" at top and bottom were reflections from the nontransparent ends of the cylindrical wall. The unwanted non-normal evanescent mode is caused by the local (leakage) field of the large input power coupling loop when power is too high.

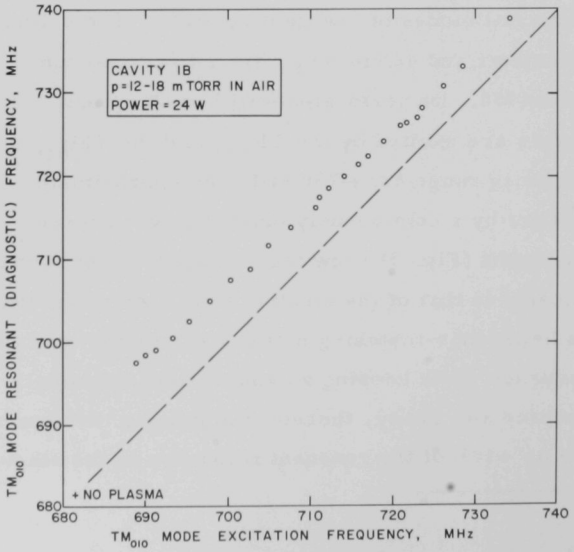

Fig. 4. Resonant frequency of the TM_{010} diagnostic mode as a function of the excitation frequency of the same mode. In this typical result, a shift of $\sim +7\frac{1}{2}\%$ in the excitation frequency at constant power results in a 7-fold increase in the plasma density as indicated by the shift in the diagnostic-mode frequency.

cavity have been made while maintaining both the plasma and the essential structure of the exciting field (mode perseverance). Corresponding shifts of diagnostic-mode frequency and measurement of luminosity indicate that the plasma densities obtained ($\sim 7 \times 10^8$ cm^{-3}) are $\sim$10 times those obtained with fixed-frequency excitation. Typical frequency-shifting results are shown in Fig. 4. Stable maintenance of the plasma in the desired mode-persevering condition requires that the impedance of the plasma-loaded cavity always be kept inductive. These frequency-shifting methods and phenomena are similar to those likely to be encountered in experiments on the confinement of rf plasma. They also appear to be generally applicable to the technology of exciting plasmas in rf cavities.

POTENTIAL-WELL THEORY OF CONFINEMENT OF PLASMAS IN NONUNIFORM RADIOFREQUENCY FIELDS

Albert J. Hatch, M. Hasan, and W. E. Smith*

Session VII

The properties of rf fields pertinent to the confinement of plasmas can be examined by considering the potential of a sample plasma sphere in the field. For a small sphere of radius a, the potential

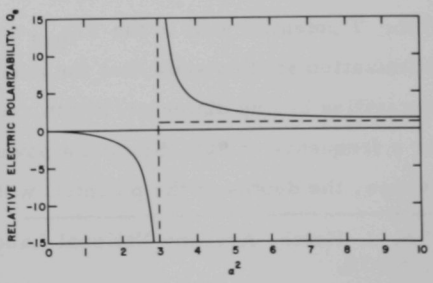

Fig. 5. Relative electric polarizability Q_e of a small plasma sphere (radius $a \ll \lambda$) of relative density a^2 in a uniform rf electric field of wavelength λ.

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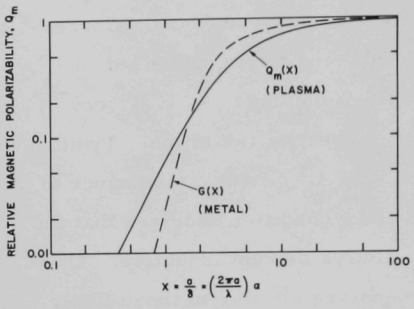

Fig. 6. Relative magnetic polarizability Q_m of a plasma sphere of relative density a^2 in a uniform rf magnetic field.

is $\Upsilon_p = \pi a^3 (\frac{1}{2} Q_m \mu_0 H^2 - Q_e \epsilon_0 E^2)$. Here $Q_m(a^2, a)$ and $Q_e(a^2)$ are the magnetic and electric polarizabilities in uniform fields of a plasma sphere of density $a^2 = (\omega_p/\omega)^2$ relative to a perfectly conducting sphere. These are shown in Figs. 5 and 6. The body force on a small sphere in a nonuniform field is $F \approx -\nabla \Upsilon$. In the low-density limit ($a^2 \to 0$) in an electric field, the well-known potential (per particle) $\Phi = (e^2/4m\omega^2)E^2$ is retrieved. In the region of intermediate density ($a^2 \approx 3$), the classical quasi-static dipole resonance of a plasma sphere in an electric field is obtained. In the high-density limit ($a^2 \to \infty$) the less-well-known potential $\Upsilon_m = \pi a^3 (\frac{1}{2} \mu_0 H^2 - \epsilon_0 E^2)$ for a metallic sphere in an electromagnetic field is obtained.

To examine the confinement properties of a given field, it is sufficient to compute Φ or Υ as a function of position in the field and to inspect the resulting topological characteristics. Both spherical[1] and cylindrical[2] cavities have been considered. The results include the contour mapping of (a) the Φ potential well in the TM_{011} mode, and (b) the Υ potential well in the TE_{012} mode of a cylindrical cavity. Optimization studies show that the maximum depths of these wells occur for cavities having diameter/length ratios of 1.5:1 and 1:1, respectively. For a frequency of 900 MHz and a power input of 2 kW into copper cavities, the depths of the potential wells per particle are 82 and 70 eV,

[1] A. J. Hatch, Argonne National Laboratory Report ANL-6455, 1961, pp. 65-79.

[2] A. J. Hatch and M. Hasan, Argonne National Laboratory Report ANL-7198, 1966, pp. 42-44.

respectively. Simple scaling relations, in which a Q gain of $\sim 10^4 - 10^5$ as obtained in superconducting cavities is assumed, show that the break-even fusion power level for the TE_{012} mode as above is in the approximate range 1—100 MW.

American Physical Society

Chicago, 29 January—1 February 1968

HYPERFINE EFFECTS IN MUONIC x RAYS OF BISMUTH

R. A. Carrigan, Jr.,* P. D. Gupta,* R. B. Sutton,* M. N. Suzuki,* A. C. Thompson,* R. E. Coté,† W. V. Prestwich,‡ A. K. Gaigalas,| and S. Raboy|

Bull. Am. Phys. Soc. 13, 65 (January 1968)

The muonic hyperfine x-ray spectrum of Bi^{209} has been studied with a resolution of 5.5 keV. The values of the M1 hfs interaction constants (A1)[1] for the $1s_{1/2}$ and $2p_{1/2}$ states were found to be (2.1 ± 0.2) keV and (1.1 ± 0.1) keV. The value of the E2 hfs interaction constant (A2) for the $2p_{3/2}$ state was found to be (-3.9 ± 0.1) keV. The measured values of the $2p_{1/2} - 1s_{1/2}$ and $3d_{3/2} - 2p_{1/2}$ lines were (5844.0 ± 1.5) keV and (2700.0 ± 0.3) keV. The parameters required to fit these values with a deformed Fermi charge distribution were c = (6.718 ± 0.012) F and t = (2.14 ± 0.04) F. These values agree with those obtained by Bardin et al.[1] from muonic x rays and by van Niftrik et al.[2] from electron scattering, but have smaller errors. The relative intensities of the hyperfine components of the $2p_{3/2} - 1s_{1/2}$ line do not agree with those expected on the assumption of a statistical population of the states, but can be explained by reducing the intensity of the F = 6 → F = 5 hfs component to (68 ± 10)% of its calculated value. This reduction can arise by the mechanism suggested by Hüfner.[3]

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|State University of New York, Binghamton, New York.

[1] T. T. Bardin et al., Phys. Rev. 160, 1043 (1967).

[2] G. J. C. van Niftrik and R. Engfer, Phys. Letters 22, 490 (1966).

[3] J. Hüfner, Z. Physik 190, 81 (1966).

HYPERFINE STRUCTURE OF LOW ATOMIC LEVELS OF La^{139}

W. J. Childs and L. S. Goodman

Bull. Am. Phys. Soc. 13, 20 (January 1968)

The hyperfine structure of the 6 lowest atomic levels of La^{139} has been examined with the atomic-beam magnetic-resonance technique. Preliminary results for the magnetic-dipole hyperfine-interaction constants A and the electronic g factors g_J are shown in Table I. The electric-quadrupole hyperfine-interaction constants B are small, and have so far been determined only very crudely. It is hoped to extend the work ultimately to about ten levels in the $5d^2 6s$ configuration.

TABLE I

Configuration	State	Excitation energy (cm^{-1})	$\|A\|$ (Mc/sec)	g_J
$5d6s^2$	$^2D_{3/2}$	0	a	0.79753(4)
	$^2D_{5/2}$	1053	a	1.19888(5)
$5d^2 6s$	$^4F_{3/2}$	2668	485(9)	0.40471(20)
	$^4F_{5/2}$	3010	301(2)	1.02944(20)
	$^4F_{7/2}$	3495	463(3)	1.23741(20)
	$^4F_{9/2}$	4122	489(3)	1.33268(20)

[a]Precision measurements of A and B were obtained by Y. Ting, Phys. Rev. 108, 295 (1957).

THE HALF-LIFE OF THE FREE NEUTRON

Carl J. Christensen

Invited paper listed by title only: Bull. Am. Phys. Soc. 13, 34 (January 1968)

ISOMER SHIFTS OF Sb AND Sn IN SOLID SOLUTIONS OF THE Sb + Sn SYSTEM

C. W. Kimball,* Hugh Montgomery,† and S. L. Ruby

Bull. Am. Phys. Soc. 13, 123-124 (January 1968)

Isomer shifts at both Sn^{119} and Sb^{121} nuclei have been measured at compositions encompassing the entire range of solid solubility of the Sb + Sn system. The previously determined values of $\delta\langle r^2\rangle$ for both nuclei have been used to obtain the changes in charge density upon alloying. For low concentrations the change in charge density with concentration is extremely small, reflecting strong screening effects. For concentrations of 2 atomic percent or more the charge density changes monotonically, increasing for both Sb and Sn with increasing electron/atom ratio e/a for Sb-rich solutions, and decreasing with increasing e/a for Sb in Sn-rich solutions. However, these changes are small, indicating that the number of electrons having s character is altered very little with varying e/a in these alloys. For pure Sn or Sb, about 1.25 s electrons are localized at each atom. As the number of electrons available changes with alloying, this number is hardly affected.

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SIMPLIFICATION OF Ge(Li) SPECTRA BY CALCULATION

J. P. Marion, L. M. Bollinger, and G. E. Thomas

Bull. Am. Phys. Soc. 13, 51 (January 1968)

This paper describes a simple but effective calculational method for subtracting out the full-energy and single-escape peaks of a γ-ray spectrum measured with a Ge(Li) detector. The only input

information is the measured spectrum, the known 511-keV spacing between the escape peaks, and the intensities α and β of the single-escape and full-energy peaks relative to the intensity of the second-escape peak. The unwanted full-energy and single-escape peaks are removed in an iterative calculation in which the intensity $N_i(E)$ at pulse energy E (in keV) for the ith iteration is obtained from the relationship

$$N_i(E) = N_0(E) - \alpha N_{i-1}(E - 511) - \beta(E)N_{i-1}(E - 1022).$$

EXCITED STATES OF As^{77} POPULATED IN THE 11-h DECAY OF Ge^{77}

D. A. McClure and H. H. Bolotin

Bull. Am. Phys. Soc. 13, 118 (January 1968)

The 11-h β^- decay of Ge^{77} has been investigated by means of γ-ray singles and coincidence spectroscopic techniques that made exclusive use of Ge(Li) solid-state detectors. Sources were produced by thermal-neutron activation of isotopically enriched samples of Ge^{76}. The high resolving power of the Ge(Li) detector system (FWHM = 2.0 keV at 1.3-MeV γ-ray energy) revealed the presence of several γ-ray transitions that were not previously reported. The γ-γ coincidence data were stored in a 1024 × 1024-channel pulse-height array on a 2-parameter magnetic tape storage unit. To prevent spectral line shifts and broadenings, digital zero and gain stabilization were employed at both ADC's during the lengthy coincidence studies. The results of these detailed studies have been incorporated in a complete and comprehensive decay scheme that differs in some important respects from those proposed by earlier investigators.

NEUTRON PARTICLE-HOLE STATES IN THE EVEN-A BARIUM ISOTOPES

G. C. Morrison, N. Williams, J. A. Nolen, Jr., and D. von Ehrenstein

Bull. Am. Phys. Soc. 13, 70 (January 1968)

Previously reported work[1] on inelastic proton scattering at isobaric analog resonances has given detailed information on certain neutron particle-hole states in Ba^{138}, namely those based on $2f_{7/2}$, $3p_{3/2}$, or $3p_{1/2}$ particle and on $2d_{3/2}$ or $3s_{1/2}$ hole configurations, respectively. The study of the states based on these configurations has now been extended to include all the even-A isotopes of Ba. In the case of Ba^{136}, information in addition to that obtained from the decay of isobaric analog resonances has been obtained from the study of the $Ba^{135}(d,p)Ba^{136}$ reaction. In some instances it is possible to make reasonable assignments of spin and parity from the data, as well as to determine the predominant configurations of individual states. The quantity $\sum\Gamma_{p'}$ over all the particle-hole states is found to be closely the same at each resonance in the same isotope. For the different Ba isotopes, the change in the sum is indicative of the variation of neutron occupation number in the $2d_{3/2}$ and $3s_{1/2}$ orbitals.

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[1] G. C. Morrison, N. Williams, J. A. Nolen, Jr., and D. von Ehrenstein, Phys. Rev. Letters 19, 592 (1967).

NEUTRON RADIUS OF Pb^{208}

J. A. Nolen, Jr., J. P. Schiffer, and N. Williams

Bull. Am. Phys. Soc. 13, 65 (January 1968)

The wavefunction of the analog state of a nucleus such as Pb^{208} is given by operating with the T_- operator on the ground state of Pb^{208}. In this process one of the excess neutrons in the target is replaced by a proton with the same quantum numbers (except T_z). The corresponding

Coulomb displacement energy ΔE_c is then given by the Coulomb interaction between one proton and the charge distribution of the parent nucleus. We assume that the radial distribution of the proton in the analog state is the same as that of the neutron excess in the parent. With ΔE_c and the parameters of the charge distribution measured experimentally, the radius of the neutron excess can be determined. We have calculated the direct and exchange contributions to ΔE_c for Pb^{208}. (The exchange contribution is about -3%.) It was necessary to make several assumptions, whose validity will be discussed. The preliminary result is that the rms radius of the neutron excess of Pb^{208} is on the order of 4% larger than that of the proton distribution.

PROTON-HOLE STATES IN Ar^{40} FROM THE $K^{41}(d,He^3)Ar^{40}$ REACTION

N. G. Puttaswamy and J. L. Yntema

Bull. Am. Phys. Soc. 13, 87 (January 1968)

The $K^{41}(d,He^3)Ar^{40}$ reaction has been studied with the 22.80-MeV beam of the Argonne cyclotron. A potassium iodide target enriched in K^{41} has been used. Angular distributions of He^3 particles, detected by a (dE/dx)-E counter arrangement, have been analyzed with the distorted-wave theory. The excitation energies (MeV) of the Ar^{40} states to which strong transitions are observed and (in parentheses) the dominant ℓ value for proton pickup are: 0.0 (2), 1.45 (2), 3.22 (0), 3.53 (2), 4.36 (0), and 5.20 (0). There is evidence for two weak groups of He^3 particles corresponding to excitation energies of 2.5 and 4.6 MeV in Ar^{40}. An $\ell=0$ pickup restricts the spins and parities of the 3.22-, 4.36-, and 5.20-MeV states to 1^+ or 2^+. Since a study of the $Ar^{40}(n,n'\gamma)$ reaction[1] had indicated a 4^+ state at 3.22 MeV, there is a possibility that there may be two states in Ar^{40} at 3.22 MeV. However, it appears that the $(n,n'\gamma)$

[1] S. C. Mathur and I. L. Morgan, Nucl. Phys. 73, 579 (1965).

results could be explained if a 2^+ assignment is made for the level at 3.22 MeV.

ENERGY DEPENDENCE OF OPTICAL-MODEL PARAMETERS IN THE ELASTIC SCATTERING OF He^3 PARTICLES BY Ca^{40} AND Ni^{58} †

B. W. Ridley,* T. W. Conlon,* and T. H. Braid

Bull. Am. Phys. Soc. 13, 117 (January 1968)

The elastic scattering of He^3 ions on targets of Ca^{40} and Ni^{58} has been studied at incident energies of 51.4, 73.2, and 81.5 MeV. The He^3 particles were obtained from the Harwell Variable Energy Cyclotron. The beam was magnetically analyzed; the particles were detected with semiconductor counters and a particle-identification system. Data were taken from 8° to 90° at 2° intervals. Optical-model fits to the angular distributions have been made using the "average" geometrical parameters reported at lower energies[1] (namely, $r_0 = 1.14$ F, $a = 0.72$ F, $r' = 1.60$ F, $a' = 0.81$ F) and varying only V and W. Excellent fits to the data were obtained and could be improved only slightly by varying all six parameters. For Ni^{58}, the well depths are $V \approx 170$ MeV, $W \approx 16-18$ MeV. There is (at most) a weak energy dependence, V falling and W rising smoothly with energy.[1] For Ca^{40}, the values are $V \approx 176$ MeV, $W \approx 15-17$ MeV and the energy dependence of V is less marked. These results are in excellent agreement with those reported at lower energies.[1] This set of parameters therefore describes He^3 scattering over a wide energy range.

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† Experimental work performed in collaboration with the staff of AERE, Harwell while T. H. Braid was on exchange at the Nuclear Physics Division, Harwell, during 1966—67.

* A. E. R. E., Harwell, England.

[1] Gibson et al., Phys. Rev. 115, 1194 (1967).

UNIMPORTANCE OF d ELECTRONS IN TIN ISOMER SHIFTS

S. L. Ruby, M. Wilson,* and Hwa-Sheng Cheng†

Bull. Am. Phys. Soc. 13, 30 (January 1968)

Some of the attempts to explain the isomer shifts seen using the Mössbauer effect with tin nuclei have invoked d electrons; their (anti)shielding effects can be used to provide another parameter for fitting experimental results to calculations. Experimentally, we have compared the shifts seen in SnX_4 with those seen in K_2SnX_6 (X = F, Cl, Br, I). We have also calculated free-atom solutions by HF-SCF methods for sp^3 and sp^3d^2 electronic configurations which are appropriate for SnX_4 and SnX_6^{--}, respectively. Both the experiments and the calculations show only small shifts between sp^3 and sp^3d^2, as compared with those created by removal of s electrons.

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†Tsing-Hua University, Taiwan, China.

OPTICAL-MODEL ANALYSIS OF PROTON ELASTIC SCATTERING FROM BORON AND BERYLLIUM

R. E. Segel, B. A. Watson, and P. P. Singh*

Bull. Am. Phys. Soc. 13, 115 (January 1968)

We have found an optical-model potential that fits the 10—20-MeV range of our recently obtained[1] elastic-scattering data on B^{10} as well as the published data[2,3] on elastic scattering on Be^9 and

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*Indiana University, Bloomington, Indiana.

[1] B. A. Watson, J. J. Kroepfl, and P. P. Singh, Bull. Am. Phys. Soc. 12, 484 (1967).

[2] F. W. Bingham, M. K. Brussel, and T. D. Steben, Nucl. Phys. 55, 256 (1964).

[3] R. H. Siemssen (private communication).

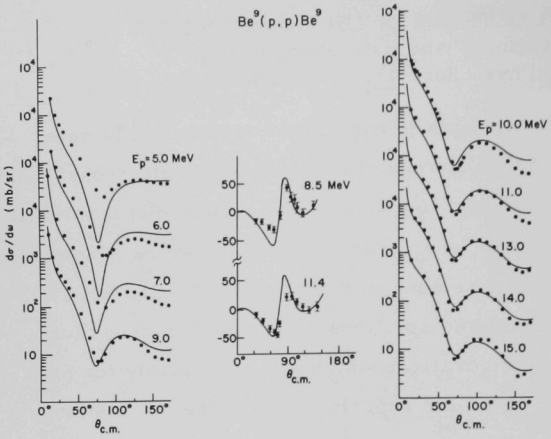

Fig. 7. Differential cross sections for protons elastically scattered from Be^9. The solid lines are optical-model fits to the data.

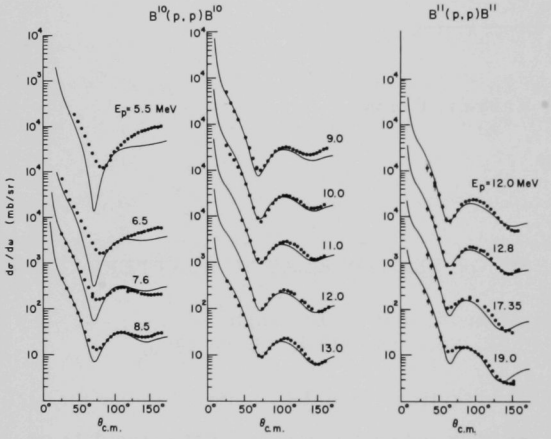

Fig. 8. Differential cross sections for protons elastically scattered from B^{10} and B^{11}. The solid lines are optical-model fits to the data.

B^{11}. Typical fits are shown in Figs. 7 and 8. The real potential and the radius parameters are those proposed by Perey[4]; forms allowing a dependence on energy and (N - Z)/A were found for the other parameters. The theory then gave good fits for Be^9 above 11 MeV, B^{10} above 10 MeV, and B^{11} above 12 MeV. Without further modification this

[4] F. G. Perey, Phys. Rev. 131, 745 (1965).

same potential fits published elastic-scattering data on N^{14} and polarizations from C^{13} + p in this energy range. The agreement is fairly good for the Li^7 + p angular-distribution and polarization data. Only for Li^6 (which may be too light) and for C^{12} (which has considerable resonance structure) is there poor agreement.

ELASTIC SCATTERING OF ALPHA PARTICLES BY Si^{28}

P. P. Singh,* R. K. Li,* D. W. Devins,* J. W. Smith,* J. J. Kroepfl,* T. P. Marvin,* and A. J. Elwyn

Bull. Am. Phys. Soc. 13, 117-118 (January 1968)

The elastic scattering of alpha particles from Si^{28} is being investigated using 100-$\mu g/cm^2$-thick and 99%-enriched targets. Measurements have been made in the alpha energy range 10.0—12 MeV in 40-keV intervals. At each energy, angular distributions are obtained in the angular range 20°—160° in 3° steps. At all angles the differential cross sections as a function of energy exhibit marked fluctuations about 80 keV in width. The angular distributions show typical diffraction patterns. A phase-shift analysis and optical-model fits to the data are under way.

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ISOMER SHIFTS OF TIN IONS IN ICE

P. K. Tseng,* S. L. Ruby, and Hwa-Sheng Cheng†

Bull. Am. Phys. Soc. 13, 30 (January 1968)

The study of ions in frozen aqueous solutions by use of the Mössbauer effect was begun by Dézsi et al.[1] and Kaplan et al.[2]

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†Duquesne University, Pittsburgh, Pennsylvania.

[1] I. Dézsi, L. Keszthelyi, B. Molnár, and L. Pócs, Phys. Letters 18, 29 (1965).

[illegible] Kaplan, Anal. Chem. (to be published).

Using Fe^{57} in various solutions, they studied mainly the variation of such parameters as f, e^2qQ, and Γ with temperature. Using Sn^{4+}, we have studied the isomer shifts (all at 78°K) for various concentrations of tin and of the anions Cl^-, Br^-, and F^-. The work to date indicates that, for fairly rapid cooling, the resultant isomer shifts depend upon the concentrations in a way that suggests the "freezing in" of the original ionic equilibria in the water.

INELASTIC SCATTERING OF PROTONS BY B^{10}

B. A. Watson, J. J. Kroepfl,* P. P. Singh,* and R. E. Segel

Bull. Am. Phys. Soc. 13, 115 (January 1968)

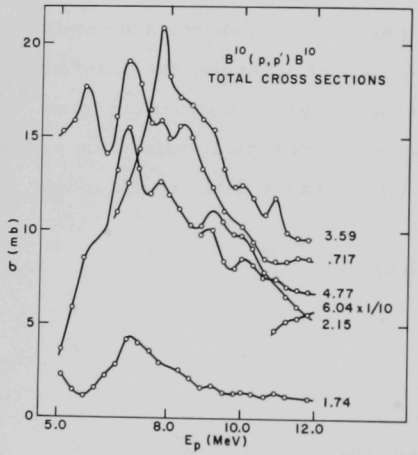

Fig. 9. Integrated total cross sections for protons inelastically scattered from states in B^{10}.

The inelastic scattering of protons by B^{10} has been studied at proton bombarding energies from 5 to 12 MeV. Data were taken every 100 keV at six angles while complete angular distributions in 5° steps from 15° to 165° were measured every 300 keV. The groups studied were those feeding the 0.72-, 1.74-, 2.15-, 3.59-, 4.77-, and 6.04-MeV states. The various groups became observable at bombarding energies about 2 MeV above their thresholds. The integrated cross sections, shown in Fig. 9, for

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feeding the 1.74-, 2.15-, and 3.59-MeV states are in reasonable agreement with those reported by Segel et al.[1] but our value for the feeding of the 0.72-MeV state is only about half theirs. By far the largest cross section observed is that for feeding the 6.04-MeV state. Over the brief range (10.9—12 MeV) where this group could be observed, its cross section was more than five times that of any other. This supports the notion that the 6.04-MeV state is the first excited state of a rotational band built upon the ground state. The angular distributions for all of the groups showed a peaking in the forward direction.

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[1] R. E. Segel, P. P. Singh, S. S. Hanna, and M. A. Grace, Phys. Rev. 145, 736 (1966).

COULOMB DISPLACEMENT ENERGIES OF THE NICKEL ISOTOPES

N. Williams, J. A. Nolen, Jr., J. P. Schiffer, and G. C. Morrison

Bull. Am. Phys. Soc. 13, 105 (January 1968)

The ground-state Coulomb displacement energies of the isobaric pairs Ni^{58}-Cu^{58}, Ni^{59}-Cu^{59}, Ni^{60}-Cu^{60}, Ni^{61}-Cu^{61}, Ni^{62}-Cu^{62}, Ni^{64}-Cu^{64}, and Ni^{66}-Cu^{66} have been measured to ±15 keV by the (He^3,p), (He^3,d), and (He^3,t) reactions at the Argonne tandem Van de Graaff and magnetic spectrograph. The Coulomb shifts for Ni^{59} and Ni^{61} were obtained with the (He^3,d) reaction—those for Ni^{58} and Ni^{66} with (He^3,t) and (He^3,p), respectively. Both (He^3,p) and (He^3,t) reactions were used to determine the shifts in Ni^{60} and Ni^{64}, and all 3 reactions were used in the determination for Ni^{62}. These results have been analyzed to extract neutron well radii r_n as was done for the calcium isotopes,[1]

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[1] J. A. Nolen, Jr., J. P. Schiffer, N. Williams, and D. von Ehrenstein, Phys. Rev. Letters 18, 1140 (1967).

but with configuration mixing and antisymmetrization effects taken into account. The data were found to be well fitted on the assumption that $r_n \propto A^{1/3}$.

GAMMA DECAY OF $T=\frac{3}{2}$ STATES IN Al^{25} AND P^{29}

D. H. Youngblood,* G. C. Morrison, R. C. Bearse, and R. E. Segel

Bull. Am. Phys. Soc. 13, 85-86 (January 1968)

The gamma decay of the lowest $T=\frac{3}{2}$ state ($J^\pi = \frac{5}{2}^+$) in P^{29} at $E_x = 8.374 \pm 0.006$ MeV has been found to populate the $\frac{3}{2}^+$ first, $\frac{5}{2}^+$ second, and $\frac{3}{2}^+$ third excited states. In Al^{25} the lowest $T=\frac{3}{2}$ state ($J^\pi = \frac{5}{2}^+$) at $E_x = 7.916 \pm 0.006$ MeV decays to the $\frac{5}{2}^+$ first and $\frac{7}{2}^+$ third excited state; but there is no discernible branch to the $\frac{3}{2}^+$ second excited state. The Al^{25} decay can be explained by the selection rules for M1 transitions which follow if the lowest $T=\frac{3}{2}$ states arise from mixing of $K=\frac{3}{2}$ and $K=\frac{5}{2}$ bands, and the low-lying states can be regarded as members of either $\frac{5}{2}^+$ or $\frac{1}{2}^+$ bands with little band mixing. The ratio of the transition probabilities to the $\frac{5}{2}^+$ and $\frac{7}{2}^+$ states are in reasonable agreement with the predictions for the $K=\frac{3}{2}$ band. The P^{29} decay, however, requires that if the low-lying states are to be considered deformed, the bands must be mixed. Angular distributions of the ground-state transitions from the two lowest $T=\frac{3}{2}$ states in Al^{25} show each to contain $\lesssim 5\%$ E2. Thus, these $\Delta T=1$ E2 transitions are not enhanced, further attesting to the isospin purity of the states.

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$Zn^{64,66,68,70}(d,He^3)$ REACTIONS AT 23.3 MeV

B. Zeidman and J. A. Nolen, Jr.

Bull. Am. Phys. Soc. 13, 105 (January 1968)

The (d,He^3) reactions induced by 23.3-MeV deuterons incident upon the stable even-mass Zn isotopes has been investigated. The He^3 particles were detected and identified with a $\Delta E \cdot E$ counter telescope. The energy resolution width in the observed spectra was approximately 55 keV. Angular distributions were obtained over the angular range $12^\circ - 30^\circ$ for levels up to about 3 MeV excitation in the residual nuclei. Transitions for the low-lying levels all involve either $\ell = 1$ or $\ell = 3$ transfer. In this work, we find $Q = -5.65 \pm 0.03$ MeV for the $Zn^{70}(d,He^3)Cu^{69}$ ground-state reaction. The systematics of the structure of the odd-mass Cu isotopes will be discussed.

Nuclear Physics and the Solid State Physics Symposium
Indian Institute of Technology, Guindy, Madras 36, India
27 February—1 March 1968

NUCLEAR STRUCTURE CALCULATIONS

R. D. Lawson

The structure of the shell-model wave functions for low-lying states of even-even nuclei is examined and it is shown why one might hope to reproduce energies and some transition rates by use of the BCS and two-quasiparticle approximations to describe single-closed-shell nuclei. By comparison with exact calculations on the nickel isotopes, it is demonstrated that if the physical quantity one wants to calculate is not symmetric about $\overline{N}$ (where $\overline{N}$ is the number of nucleons in the physical system one wants to describe) large errors result when the BCS and two-quasiparticle wave functions are used. To remedy this deficiency it is necessary to project out of these wave functions the part describing a system with $\overline{N}$ particles, normalize this part, and then use the normalized projected eigenfunction to calculate the physical quantity of interest. It is also shown that if one does only a two-quasiparticle calculation for the low-lying excited states one can only reliably predict the B(E2) between the ground state and the first 2^+ nuclear level.

Eleventh Scintillation and Semiconductor Counter Symposium
Washington, D.C., 28 February—1 March 1968

TIME DEPENDENCE OF SCINTILLATIONS AND THE EFFECT ON PULSE-SHAPE DISCRIMINATION

Franca T. Kuchnir and
Frank J. Lynch

The time dependence of the light following excitation by gamma rays and neutrons was measured for stilbene and for the liquids NE-213, NE-213M, and NE-218.[1] In addition, the number of photoelectrons produced at the cathode of an RCA-8575 photomultiplier per keV energy loss in the scintillator has been determined for each of these scintillators. A straightforward technique for pulse-shape discrimination is described; it consists in measuring the time difference between the start and the instant at which the integrated photomultiplier pulse reaches a specified fraction k of its final amplitude. From the measured scintillation decay, the probability distribution of these rise times has been calculated for different fractions k and for different photon and neutron

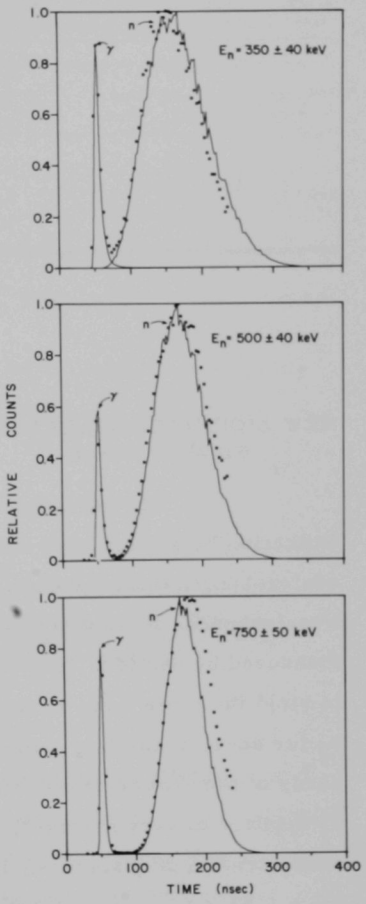

Fig. 10. Rise-time distributions for γ rays and neutrons. The points are experimental values. The curves were calculated by use of the equations developed.

[1] Liquid scintillators purchased from Nuclear Enterprises, Ltd., Winnipeg, Manitoba, Canada.

TABLE II. Percentages of neutrons and gamma rays counted with an integral discriminator at three successively higher settings on the rise-time distribution (Fig. 10).

Neutron energy (keV)	Fraction of neutrons accepted (%)	Fraction of γ rays accepted (%)
350 ± 50	90	1.37
	80	0.97
	70	0.70
500 ± 40	90	0.20
	80	0.14
	70	0.11

energies on the assumption of Poisson statistics. Figure 10 compares the measured rise-time distributions (points) with the distributions (curves) calculated with k = 0.895. Table II shows the fractions of the total numbers of neutrons and gamma rays that would be counted for different settings of an integral discriminator on the rise-time spectrum.

NEW LIQUID SCINTILLATORS WITH HIGHER SPEED AND EFFICIENCY

Frank J. Lynch

The variation of light intensity with time following excitation by gamma rays has been measured for toluene solutions of quaterphenyl, quinquiphenyl, and sexiphenyl compounds whose solubilities were enhanced by substitution of alkyl groups. The decay curves, measured by use of a light-intensity-sampling technique, were analyzed to yield the mean lives τ_1 for energy transfer from solvent to solute, τ_2 for decay of the fast component (from the singlet state), and τ_3 for decay of the slower component (probably from excimers). As expected, τ_1 appears to vary inversely with solute concentration, and at the highest concentration of quaterphenyl in toluene ($\sim$65 g/liter, mole fraction = $\gamma = 1.12 \times 10^{-2}$) was < 0.1 nsec. At this concentration, the amount of light in the slower component was only about $\frac{1}{6}$ of the total light. This indicates that formation of excimers is inhibited. In addition, the photoelectrons produced in an RCA-8575 photomultiplier per keV of energy lost in the scintillator was measured. Table III summarizes

TABLE III. Relative light output and time constants. The relative light output and the number of photoelectrons per keV were measured with a bialkali photocathode (RCA-8575). The values shown for τ_1 and τ_2, the mean lives for energy transfer and decay, are those for which the experimental data are best fitted by the equation

$$I^*(T) = \frac{P(t)\{\exp[-(T-t)/\tau_1)] - \exp[-(T-t)/\tau_2)]\}}{\tau_1 - \tau_2}\,dt,$$

where P(t) is the response of the measuring system to a delta function of light. The mean life τ_3 for the longer component was estimated from the slope of the semilogarithmic plot at long times (10—30 nsec).

Scintillators	Mole fraction	Relative pulse height	P (p.e./keV)	τ_1 (nsec)	τ_1 (min) (nsec)	τ_2 (nsec)	τ_3 (est) (nsec)
Liquids[a]							
PPO		100	1.7			1.55	9
PBD		112	1.9				
P4-G12	$5 \cdot 10^{-3}$	124	2.1	0.15	0.07	1.27	8
P5-B9	$2.5 \cdot 10^{-3}$	130	2.2	0.2	0.1	1.22	9
TMSP	$1.8 \cdot 10^{-3}$	112	1.9	0.15	0.15	1.02	6.5
Glasslike[b]							
TMQP	1.0	92	1.6	<0.05	<0.05	1.08	11.5
Plastics[c]							
Pilot B		90	1.5	0.4		1.6	9.5
Naton 136		80	1.4	0.4		1.6	10
Crystals							
Stilbene		140	2.4	0.1		4.05	
NaI(Tl)		520	9.0				

[a] Liquids are dissolved in toluene with oxygen removed. PPO: diphenyl oxazole. PBD: phenyl-biphenyl-oxadiazole. P4-G12: 1^1, 4^4-bis (2-butyloctyloxy)-P-quaterphenyl. P5-B9: 1^2, 5^3-bis (3-ethylheptyl)-P-quinquiphenyl. TMSP: 1^2, 2^3, 5^2, 6^3-tetramethyl-P-sexiphenyl.

[b] TMQP: 1^2, 2^3, 3^2, 4^3-tetramethyl-P-quaterphenyl.

[c] Pilot B: Pilot Chemical Co. Naton 136: Nash-Thompson Ltd.

the results of the measurements. The improvement in efficiency and speed is reflected in a corresponding improvement in the time resolution achievable with these scintillators. For a 300-keV energy loss in the quaterphenyl solution, the FWHM was 0.20 nsec and the effective half-life was 0.035 nsec.

Second Conference on Neutron Cross Sections and Technology
Washington, D.C., 4—7 March 1968

TOTAL NEUTRON CROSS SECTIONS OF ^{6}Li, ^{7}Li, AND LITHIUM FROM 10 TO 1236 keV

C. T. Hibdon and F. P. Mooring

The total cross sections of ^{6}Li and natural lithium have been measured by the transmission method for neutrons in the energy range 10—1236 keV, and the total cross section of ^{7}Li was extracted from the results. Except for a range of energies near 250 keV, the neutron energy spread was ~2 keV. No structure other than a large resonance in the cross section of ^{6}Li at 250 keV and in the cross section of ^{7}Li at 260 keV was observed. These two resonances were investigated by both flat-detection and self-indication techniques, in each case with neutron energy spreads of ~1 keV and ~8 keV. The measured peak height of each of these resonances disagrees with the theoretical value for any possible value of J. Values of the total cross section at resonance obtained by the self-indication technique exceed those obtained by flat indication by a statistically significant amount. However, the anomalously high value for the ^{6}Li cross section was reduced by about 0.3 barns by more highly collimating the transmitted neutron flux. Thus it seems likely that the measured difference between flat and self-indication values is spurious and is probably instrumental in nature.

Conference on Low- and Medium-Energy Nuclear Physics
A.E.R.E., Harwell, Berkshire, England, 27—29 March 1968

ELASTIC SCATTERING OF ^{3}He AND ^{4}He IONS AT INTERMEDIATE ENERGIES*

T. H. Braid, B. W. Ridley,† and T. W. Conlon‡

The elastic scattering of ^{3}He and ^{4}He ions from ^{40}Ca and ^{58}Ni has been studied over the energy range 22—86 MeV using beams accelerated by the Harwell Variable Energy Cyclotron. The energies used were E(^{3}He) = 22.0, 37.7, 43.7, 51.4, 73.2, and 83.0 MeV, and E(^{4}He) = 24.3, 40.0, 52.4, 59.0, 67.7, 85.6 MeV. The scattering was observed in a 26-in. scattering chamber which has an angular precision of 3' of arc. Angular distributions were taken over the range 8°—90° lab at 2° intervals in a typical case.

Particles elastically scattered from thin foils of ^{40}Ca and ^{58}Ni were counted in a Si(Li) detector in the case of the ^{4}He ions and by a counter telescope consisting of a thin ΔE transmission detector backed by a Si(Li) counter in the case of ^{3}He ions. In the latter case, masses were distinguished by forming a product of the form $EdE/dx \approx KMZ^2$ in order to separate reliably the scattered ^{3}He ions from ^{4}He ions produced as a reaction product. Small movements of the beam across the target could be observed and corrected for by monitoring particles elastically scattering at small angles to the beam line. Two Si(Li) detectors were permanently mounted at $\pm 15^\circ$ for this purpose.

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*Experimental work performed in collaboration with the staff of A.E.R.E., Harwell while T. H. Braid was on exchange at the Nuclear Physics Division, Harwell, during 1966—67.

†University of Colorado, Boulder, Colorado, and A.E.R.E., Harwell, Berkshire, England.

‡A.E.R.E., Harwell, Berkshire, England.

A theoretical analysis of the elastic scattering is being carried out in terms of the optical model. For the ^{3}He scattering, fits to the angular distribution have been made using "average" geometric parameters closely related to those reported at lower energies[1] [namely, $r_0 = 1.14$ F, $a = 0.715$ F, $r' = 1.60$ F (for ^{58}Ni) and 1.66 F (for ^{40}Ca), $a' = 0.829$ F, $r_c = 1.40$ F] and varying only V and W. Excellent fits to the data were obtained and could be improved only slightly by varying all six parameters.

The general conclusions are that for both ^{40}Ca and ^{58}Ni in the region 30—83 MeV, ^{3}He scattering can be well described by constant potentials, namely,

$$V = 177.2 \text{ MeV}, \quad W = 15.6 \text{ MeV} \quad \text{for } ^{40}\text{Ca}$$

and

$$V = 170.1 \text{ MeV}, \quad W = 17.4 \text{ MeV} \quad \text{for } ^{58}\text{Ni},$$

and with the geometric parameters fixed as above.

Even better agreement with the data is obtained if an energy-dependent term is included in the real well depth so that

$$V = 174.4 - 0.07(1)\, E \text{ MeV} \quad \text{for } ^{58}\text{Ni},$$

$$V = 181.1 - 0.07(6)\, E \text{ MeV} \quad \text{for } ^{40}\text{Ca}.$$

The corresponding values for the imaginary potentials are

$$W = 17.3 + 0.0\, E \quad \text{for } ^{58}\text{Ni},$$

$$W = 14.6 + 0.01(4)\, E \quad \text{for } ^{40}\text{Ca}.$$

A similar analysis for the ^{4}He data is in progress.

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[1] Gibson et al., Phys. Rev. 115, 1194 (1967).

III. ABSTRACTS OF PAPERS ACCEPTED FOR PUBLICATION

LIFETIMES OF THE FIRST FOUR EXCITED STATES IN Si^{29}

S. I. Baker and R. E. Segel

Phys. Rev. (20 June 1968)

The attenuated-Doppler-shift method was used to measure the lifetimes of the first four excited states in Si^{29}. The states were populated by the $Si^{28}(d,p)$ reaction and the direction of a recoil was defined by the direction of the outgoing proton with which it was in coincidence. The shifts were measured both for the stopping of recoils in a heavy material (gold) and for stopping in a light material (silicon or carbon). The lifetimes of these excited states were found to be $3.1^{+1.1}_{-0.8} \times 10^{-13}$ sec for the first, $3.5^{+0.9}_{-0.8} \times 10^{-13}$ sec for the second, $(2.0 \pm 0.7) \times 10^{-14}$ sec for the third, and $(2.3 \pm 1.1) \times 10^{-14}$ sec for the fourth. It is concluded that no simple picture adequately describes the low-lying states in Si^{29}, but that a mixture of two rotational bands shows promise.

SEVERELY INHIBITED E2 TRANSITION IN ^{41}Sc

R. C. Bearse, D. H. Youngblood, and R. E. Segel

Nucl. Phys. (1968)

The $^{40}Ca(p,\gamma_0)^{41}Sc$ yield curve was examined in a search for the transition from the $\frac{3}{2}^-$ third excited state to the $\frac{7}{2}^-$ ground state in ^{41}Sc. No resonance was found, and an upper limit of $\Gamma_{\gamma_0} = 10$ μeV, which corresponds to 6×10^{-3} single-particle units, was set.

PROTON HOLE STATES IN ^{29}Al, ^{31}P, AND ^{33}P

R. C. Bearse, D. H. Youngblood, and J. L. Yntema

Phys. Rev. (20 March 1968)

The low-lying states in ^{29}Al, ^{31}P, and ^{33}P have been studied via the reactions $^{30}Si(d,^3He)^{29}Al$, $^{26}Mg(\alpha,p)^{29}Al$, $^{32}S(d,^3He)^{31}P$, $^{34}S(d,^3He)^{33}P$, and $^{30}Si(\alpha,p)^{33}P$. Spectroscopic factors have been

extracted for the (d, ^{3}He) reactions leading to two final states in ^{29}Al, three in ^{31}P, and two in ^{33}P. In the ^{30}Si(d, ^{3}He)^{29}Al reaction, we observed $\ell=2$ and $\ell=0$ angular distributions from reactions leading to the ground state and first excited state, respectively. For the ^{34}S(d, ^{3}He)^{33}P reaction, we obtained an $\ell=0$ distribution for the reaction to the ground state and an $\ell=2$ distribution for the reaction to the second excited state.

THE PHOTOIONIZATION OF CADMIUM AND MERCURY VAPOURS

J. Berkowitz and C. Lifshitz

Proc. Phys. Soc. (London)

A windowless vacuum ultraviolet monochromator was used for the study of the photoionization curves of cadmium and mercury. The energy range covered was from the onsets of ionization to 19 eV and 17.7 eV for cadmium and mercury, respectively. Several autoionization peaks were observed. These correspond to excitations of inner d electrons of the neutral atoms. Oscillator strengths are given for the autoionization peaks in cadmium.

LEVEL STRUCTURE OF LOW-LYING EXCITED STATES OF Sc^{46}

H. H. Bolotin

Phys. Rev. (20 April 1968)

The low-lying excited states of Sc^{46} populated by primary and secondary γ-ray transitions from the $Sc^{45}(n,\gamma)Sc^{46}$ thermal-neutron-capture reaction were studied. Ge(Li) detectors were used exclusively in both singles and coincidence γ-ray investigations. High-energy primary γ-ray spectra were obtained and were used to infer the excitation energies of 53 states up to $\sim$2600 keV. The neutron binding energy was determined to be 8767 $\pm$ 1 keV. Coincidence investigations between high-energy ($\sim$7—9 MeV) and low-energy ($\lesssim$2 MeV) γ rays, as well as among the low-energy transitions, have allowed a total of 23 low-energy transitions to be assigned between states up to an excitation energy of 1324 keV. A level and decay scheme is proposed for a total of 57 excited states below an energy of 2600 keV. This scheme differs in several important respects from those proposed previously. The observed characteristics of these states are compared with the most recent charged-particle reaction studies, previous bent-crystal-spectrometer γ-ray results, and available theoretical calculations.

MUONIC x RAYS FROM SEPARATED ISOTOPES OF EUROPIUM

R. A. Carrigan, Jr.,* P. D. Gupta,* R. B. Sutton,* M. N. Suzuki,* A. C. Thompson,* R. E. Coté, W. V. Prestwich, A. K. Gaigalas,† and S. Raboy†

Phys. Rev. Letters (15 April 1968)

Muonic K and L x rays have been observed with a Ge(Li) detector for separated isotopes of europium. A modified Fermi charge distribution was used for the analysis of both nuclei. The Eu^{153} spectrum was fitted by assuming the validity of the rotation model; for the Eu^{151}, excitation to only the low-lying 21.7-keV state was invoked. The analysis yields values for several level parameters that agree well with the available data.

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*Carnegie-Mellon University, Pittsburgh, Pennsylvania.

†State University of New York, Binghamton, New York.

HYPERFINE STRUCTURE OF SEVEN LOW ATOMIC LEVELS IN Co^{59}, AND THE NUCLEAR ELECTRIC-QUADRUPOLE MOMENT

W. J. Childs and L. S. Goodman

Phys. Rev. (5 June 1968)

The hyperfine structure of the seven lowest atomic levels in Co^{59} has been examined with the atomic-beam magnetic-resonance technique. Quantitative agreement with earlier measurements is found for those states for which results have been published. All of the results are corrected for the effects of off-diagonal hyperfine interactions, and the effective-operator theory used for the interpretation also takes into account such effects as intermediate coupling, configuration interaction, and relativistic effects. The emphasis is on examining the consistency of the results from state to state. Although a very high degree of agreement between theory and experiment is found, some difficulty is encountered in understanding details of the quadrupole interaction. Values for the quadrupole moment of the Co^{59} nuclear ground state are determined in each of two electron configurations. The difference between the two values found is well outside experimental error and is presumably due to different Sternheimer shielding in the two configurations. The value found for Q is consistent with earlier determinations and with nuclear theory. Values are given for the electronic g factor in each state examined.

HYPERFINE-STRUCTURE STUDIES OF Ni^{61}, AND THE NUCLEAR GROUND-STATE ELECTRIC QUADRUPOLE MOMENT

W. J. Childs and L. S. Goodman

Phys. Rev. (5 June 1968)

The hyperfine structure of the four lowest atomic levels of Ni^{61} has been studied by the atomic-beam magnetic-resonance technique. Agreement between the results and the theory of the hyperfine interaction is good. The importance of taking account of the substantial departure of the atom from the LS limit in evaluating the electric quadrupole moment Q of the Ni^{61} nuclear ground state is discussed. Values of Q are determined from two different electron configurations; the values obtained differ by only 3%. The result is in agreement with the previous theoretical prediction of S. Cohen et al.

MASS-SPECTROMETRIC STUDY OF THE PHOTOIONIZATION OF METHANE

William A. Chupka

J. Chem. Phys. (15 February 1968)

Photoionization efficiency curves for the parent and fragment ions of CH_4 have been measured with photon bandwidths of 1.6 and 0.4 Å. For the fragment ions, the effect of thermal rotational energy at room temperature is apparent in the threshold region and was taken into account to obtain accurate thresholds. The bond energy D°_0 (CH_3-H) was determined to be 4.477 ± 0.005 eV and the limit $\Delta H^{\circ}_{f_0}(CH_2) \leq 4.10$ eV was found. Ion-pair formation yielding CH_3^+ and H^- was found to occur with low probability.

ION-MOLECULE REACTIONS OF NH_3^+ BY PHOTOIONIZATION

W. A. Chupka and M. E. Russell

J. Chem. Phys. (15 February 1968)

Photoionization-efficiency curves were measured for NH_3^+, NH_4^+, and H_3O^+ ions in NH_3 gas and in gaseous mixtures of NH_3 and H_2O. The results are interpreted to determine how the relative reaction cross section depends on the vibrational energy of the NH_3^+ ion for the reactions

$$NH_3^+ + NH_3 \rightarrow NH_4^+ + NH_2 , \quad (1)$$

$$NH_3^+ + H_2O \rightarrow NH_4^+ + OH . \quad (2)$$

The cross section for Reaction (1) decreases with increasing vibrational energy while that for Reaction (2) is nearly independent of vibrational energy. The results are discussed in terms of the formation of an intermediate complex and in terms of stripping models. The upper limit of the proton affinity was determined to be ≥ 8.54 eV for NH_3 and ≥ 7.0 eV for H_2O.

PHOTOIONIZATION STUDY OF ION-MOLECULE REACTIONS IN MIXTURES OF HYDROGEN AND RARE GASES

W. A. Chupka and Morley E. Russell

J. Chem. Phys.

The reactions producing HeH^+, NeH^+, and ArH^+ in mixtures of hydrogen with rare gases were studied by photoionization mass spectrometry. The HeH^+ and NeH^+ ions are produced by vibrationally excited H_2^+ ions; the thresholds for reaction were found to be very near the $v = 3$ and $v = 2$ states of H_2^+, respectively. Above the vibrational threshold the reaction cross section increases with vibrational quantum number and there is no evidence for a kinetic energy threshold for these states. When accelerated to sufficient kinetic energy, H_2^+ ions in vibrational states below threshold react with a cross section which increases as the deficit in vibrational energy decreases. The rate constant for reaction of those vibrational states that are near or above the reaction threshold and that contribute most to the observed reaction becomes nearly constant at low repeller voltages. The threshold for the reaction producing HeH^+ can be made consistent with a theoretical value for the dissociation energy $D_0(HeH^+) = 1.835$ eV. The difference $D_0(NeH^+) - D_0(HeH^+)$ is found to be 0.25 ± 0.03 eV. This yields $D_0(NeH^+) = 2.085$ eV. In argon-hydrogen mixtures, the ArH^+ ion is formed in an exothermal reaction between H_2^+ in all vibrational states and Ar^+ ions in the $^2P_{3/2}$ ground state and (with $\sim 30\%$ larger cross section) with Ar^+ in the $^2P_{1/2}$ excited state. The cross section has little or no dependence on vibrational energy. Chemi-ionization processes leading to the formation of ArH^+ by excited H^* and Ar^* atoms were observed. The dissociation energy of ArH^+ was found to be certainly greater than 2.647 eV and, from a tentative interpretation of the chemi-ionization processes, probably greater than 3.397 eV.

ION-MOLECULE AND CHEMI-IONIZATION REACTIONS IN H_2 BY PHOTOIONIZATION

W. A. Chupka, M. E. Russell, and K. Refaey

J. Chem. Phys.

The production of H_3^+ by ion-molecule and chemi-ionization processes initiated by photon impact in H_2 has been studied as a function of photon energy with resolution widths varying from 0.05 to 0.002 eV. The purpose was to determine how the vibrational energy of the reactant ion affects the reaction cross section. The data indicate that the reaction $H_2^+ + H_2 \rightarrow H_3^+ + H$ proceeds by at least two different mechanisms. At very low kinetic energies, the dominant mechanism has a reaction cross section which decreases slowly as the vibrational energy of the ion increases. At higher kinetic energy, a mechanism for which the cross section increases with increasing vibrational energy of the ion becomes more prominent. The characteristics of the first mechanism suggest the formation of a collision complex while those of the latter suggest a mechanism such as stripping. At low kinetic energies, the rotational energy of the ion has only a small effect on the reaction cross section. Some of the production of H_3^+ by chemi-ionization below the ionization threshold of H_2 is shown to involve excited H atoms, probably in the 2^2S metastable state, as well as excited H_2 molecules. The cross section for chemi-ionization by excited H atoms was found to decrease with kinetic energy; this behavior is discussed. The proton affinity of H_2 was found to be ≥ 3.936 eV.

MAGNETIC-FIELD-INDUCED QUADRUPOLE SPLITTING

R. M. Golding

Molecular Physics (1968)

The general expression for the magnetic-field-induced quadrupole splitting is derived for d^n transition metal ions in a crystal field of octahedral symmetry. The effective magnetic field may arise from either an applied field or a molecular field. Bonding effects are also treated. The temperature dependence of the quadrupole splitting ΔE_Q induced by an applied magnetic field is calculated for ^{57}Fe high-spin ferrous and low-spin ferric compounds where the ions are in crystal fields of octahedral symmetry.

DISTRIBUTION LAWS FOR THE ROOTS OF A RANDOM ANTISYMMETRIC HERMITIAN MATRIX

M. L. Mehta and N. Rosenzweig

Nucl. Phys. (26 February 1968)

In conjunction with the study of the perturbations of the statistical properties of nuclear spectra produced by interactions which are odd under time reversal, it was found that the case in which the odd part is very large can be treated analytically. While of no immediate physical interest, the precise results obtained serve as a check on the adequacy of the Monte-Carlo calculations reported in the preceding paper. With the help of the theory of random matrices, analytical results are obtained for the distribution of widths, the level density, two-level cluster function, and the distribution of the spacing between adjacent energy levels.

STUDIES OF XENON CHLORIDES AND OTHER XENON COMPOUNDS BY THE MÖSSBAUER EFFECT IN ^{129}Xe

G. J. Perlow and M. R. Perlow

J. Chem. Phys. (1 February 1968)

The compounds $XeCl_2$ and $XeCl_4$ have been made in the beta decay of ICl_2^- and ICl_4^- containing radioactive ^{129}I. The electric-quadrupole interaction in the 39.6-keV excited state of the ^{129}Xe nucleus is employed to study these substances by the Mössbauer effect. The decay products are compared with XeF_2 and XeF_4 and with the parent ions. It is shown that the decays $ICl_2^- \rightarrow XeCl_2$ and $ICl_4^- \rightarrow XeCl_4$ both result in the recall of 0.2 electrons per bond from each ligand to the central atom. In the xenon halides the charge per fluorine is -0.72 and per chlorine is -0.5. The assumption of pure p_σ bonding in the xenon halides is tested by the isomer shifts. With its aid the shifts can be calibrated by the quadrupole couplings. A shielding constant obtained from Hartree-Fock calculations by Wilson is then used to relate p-electron to s-electron transfer, which is next employed to examine the charges on the xenon atom in XeO_4 and XeO_6^{-4}. The former is prepared in beta decay, the latter equivalently either in beta decay or in bulk. It is shown that directed sp^3d^2 hybrid bonds for XeO_6^{-4} are inconsistent with the measured isomer shift. The recoilless fractions and linewidths are tabulated for a number of xenon compounds.

PHOTOIONIZATION OF THE LOWER ALIPHATIC ALCOHOLS WITH MASS ANALYSIS

Kamel M. A. Refaey and William A. Chupka

J. Chem. Phys.

Relative photoionization cross section curves have been determined for parent and fragment ions of methanol, ethanol, n-propanol, and iso-propanol over the photon energy range from the ionization potential to 14.0 eV. Appearance potentials and heats of formation of some fragment ions have been determined. The data have been treated to give experimental breakdown curves which are compared with those obtained by charge exchange and with the results of theoretical calculations. Some details of the fragmentation processes are elucidated.

PERTURBATION OF THE STATISTICAL PROPERTIES OF NUCLEAR STATES AND TRANSITIONS BY INTERACTIONS THAT ARE ODD UNDER TIME REVERSAL

N. Rosenzweig, J. E. Monahan, and M. L. Mehta

Nucl. Phys. (26 February 1968)

It is found that a rather small time-reversal-odd part in the nuclear Hamiltonian would produce an appreciable perturbation in the Porter-Thomas distribution of widths and also in the distribution of the spacings between energy levels. A comparison between the experimentally determined variances for some published neutron widths and partial radiation widths and the calculated variance allows one to place an upper limit on the magnitude of the time-reversal-odd part. The shift of the spacing distribution is particularly large on a percentage basis in the region of small spacings. As a measure of the time-reversal-odd part of the wave function, the overlap $|\psi, T\psi|$ has been evaluated. All conclusions are based on a Monte-Carlo calculation with random Hermitian matrices having a small imaginary part.

SUPER-TRANSFERRED HYPERFINE INTERACTIONS AT DIAMAGNETIC IONS IN FERRIMAGNETIC INSULATORS

S. L. Ruby, B. J. Evans,* and S. Hafner*

Solid State Communications (May 1968)

Large magnetic fields at antimony nuclei octahedrally surrounded by oxygen in ferrimagnetic spinels have been measured. These results are similar to those found earlier for tin in garnets. In order to explain these fields as resulting mainly from spin polarization of the outer 5s electrons of these ions, the magnitude of this polarization must be rather large (10—20%).

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*University of Chicago, Chicago, Illinois.

CONCENTRATION DEPENDENCE OF TIN(IV) ISOMER SHIFTS IN ICE

S. L. Ruby, P. K. Tseng, Hwa-Sheng Cheng,* and N. C. Li*

Chem. Phys. Letters (May 1968)

Sn(IV) isomeric shifts in ice have been studied as a function of concentration of added HX (X = F, Cl, Br, I). The results suggest that the number of halide nearest neighbors appropriate to water is frozen in by quick freezing. This provides a new method for the study of complex ions of tin.

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*Duquesne University, Pittsburgh, Pennsylvania.

IV. PUBLICATIONS SINCE THE LAST REPORT

PAPERS AND BOOKS

A SHELL-MODEL STUDY OF THE ISOTOPES OF O, F, AND Ne
A. Arima, S. Cohen, R. D. Lawson, and M. H. Macfarlane
Nucl. Phys. A108, 94-112 (1968)

MEASUREMENT OF THE POLARIZATION OF THERMAL NEUTRON BEAMS OF MIXED VELOCITIES
S. H. Barkan, E. Bieber, M. T. Burgy, S. Ketudat, V. E. Krohn, P. Rice-Evans, and G. R. Ringo
Rev. Sci. Instr. 39, 101-104 (January 1968)

PROTON HOLE STATES IN ^{29}Al, ^{31}P, AND ^{33}P
R. C. Bearse, D. H. Youngblood, and J. L. Yntema
Phys. Rev. 167, 1043-1048 (20 March 1968)

VIBRATIONS AND THERMODYNAMIC PROPERTIES OF HEXASULFUR
Joseph Berkowitz, W. A. Chupka, Edward Bromels,* and R. Linn Belford*
J. Chem. Phys. 47, 4320-4324 (1 December 1967)

MAGNETIC MOMENT OF THE FIRST EXCITED STATE IN ^{133}Cs BY THE MÖSSBAUER EFFECT
L. E. Campbell and G. J. Perlow
Nucl. Phys. A109(1), 59-61 (1968)

LINEWIDTH OF MÖSSBAUER ABSORPTION
Juergen Heberle
Nucl. Instr. Methods 58, 90-92 (1968)

REVIEW OF "G. E. BROWN, UNIFIED THEORY OF NUCLEAR MODELS AND FORCES"†
D. R. Inglis
Science 159 (No. 3810), 73 (5 January 1968)

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*University of Illinois, Urbana, Illinois.

†Second edition, North-Holland Publishing Co., Amsterdam, 1967.

INFINITE SYSTEMS OF CLASSICAL PARTICLES
Amnon Katz
J. Math. Phys. 8, 2451-2459 (December 1967)

DISTRIBUTION LAWS FOR THE ROOTS OF A RANDOM ANTISYMMETRIC HERMITIAN MATRIX
M. L. Mehta and N. Rosenzweig
Nucl. Phys. A109(2), 449-456 (26 February 1968)

THE GIANT DIPOLE RESONANCE EXCITED BY α CAPTURE
L. Meyer-Schützmeister, Z. Vager, R. E. Segel, and P. P. Singh
Nucl. Phys. A108(1), 180-208 (1968)

PERTURBATION OF THE STATISTICAL PROPERTIES OF NUCLEAR STATES AND TRANSITIONS BY INTERACTIONS THAT ARE ODD UNDER TIME REVERSAL
N. Rosenzweig, J. E. Monahan, and M. L. Mehta
Nucl. Phys. A109(2), 437-448 (26 February 1968)

INTERNAL MAGNETIC FIELD AT AN ANTIMONY IMPURITY IN IRON OR NICKEL
S. L. Ruby and C. E. Johnson*
Phys. Letters 26A(2), 60-61 (18 December 1967)

STUDY OF THE (d,p) REACTION IN THE 1p SHELL
J. P. Schiffer, G. C. Morrison, R. H. Siemssen, and B. Zeidman
Phys. Rev. 164, 1274-1284 (20 December 1967)

Erratum: COMPLETE $(f_{7/2})^2$ SPECTRUM OF Sc^{42} [Phys. Rev. Letters 19, 1482-1484 (25 December 1967)]
J. J. Schwartz,† D. Cline,† H. E. Gove,† R. Sherr,‡ T. S. Bhatia,‡ and R. H. Siemssen
Phys. Rev. Letters 20, 175 (22 January 1968)

FERROMAGNESIAN SILICATE ABUNDANCES IN BRONZITE CHONDRITES AS DETERMINED BY THE MÖSSBAUER EFFECT
E. L. Sprenkel-Segel and G. J. Perlow
Icarus 8, 66-74 (January 1968)

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*A.E.R.E., Harwell, Didcot, Berks., England.

†University of Rochester, Rochester, New York.

‡Princeton University, Princeton, New Jersey.

STUDY OF THE (d,p) REACTIONS ON $Zn^{64,66,68,70}$
D. von Ehrenstein and J. P. Schiffer
Phys. Rev. 164, 1374-1385 (20 December 1967)

THE REACTION $^{25}Mg(^{3}He,d)^{26}Al$ AT 12 MEV
A. Weidinger,* R. H. Siemssen,* G. C. Morrison, and B. Zeidman
Nucl. Phys. A108(3), 547-560 (1968)

SPEED OF THE $\Delta J=1$, $\Delta T=1$ M1 TRANSITION IN Al^{26}
D. H. Youngblood, R. C. Bearse, N. Williams, A. E. Blaugrund, and R. E. Segel
Phys. Rev. 164, 1370-1374 (20 December 1967)

REPORTS AT MEETINGS

in Fifth International Conference on the Physics of Electronic and Atomic Collisions, Leningrad, USSR, 17-23 July 1967; Abstracts of Papers, edited by I. P. Flaks and E. S. Solovyov (Publishing House "Nauka," Leningrad, 1967)

HIGH-RESOLUTION PHOTOIONIZATION AND MASS ANALYSIS OF SMALL MOLECULES
J. Berkowitz and W. A. Chupka
pp. 608-610

Proceedings of the International Congress on Magnetism, Boston-Cambridge, Massachusetts, 11-15 September 1967

TEMPERATURE DEPENDENCE OF ISOMER SHIFT AND HYPERFINE FIELD NEAR THE CURIE POINT IN IRON
R. S. Preston
J. Appl. Phys. 39(2), 1231 (1 February 1968)

American Physical Society, Division of Plasma Physics, Austin, Texas, 8-11 November 1967

PERSEVERANCE OF NORMAL MODES IN A PLASMA-LOADED RESONANT CAVITY
A. J. Hatch, S. L. Halverson (Electronics), and A. E. Froehlich
Bull. Am. Phys. Soc. 13, 301 (February 1968)

*Yale University, New Haven, Connecticut.

Colloque International sur l'Interaction des Champs H. F. (Appliques ou Auto Engendres) Associes a un Champ Magnetique Statique avec un Plasma (L'Institut National des Sciences et Techniques Nucleaires et la Direction de la Physique, Saclay, France, 1968)

FREQUENCY-SHIFTING METHOD OF EXCITING PLASMAS IN FUNDAMENTAL-MODE RESONANT CAVITIES
Albert J. Hatch, S. L. Halverson (Electronics), and A. E. Froehlich
Session VII

POTENTIAL-WELL THEORY OF CONFINEMENT OF PLASMAS IN NONUNIFORM RADIOFREQUENCY FIELDS
Albert J. Hatch, M. Hasan, and W. E. Smith (Applied Mathematics)
Session VII

American Physical Society, Chicago, 29 January-1 February 1968

HYPERFINE EFFECTS IN MUONIC x RAYS OF BISMUTH
R. A. Carrigan, Jr.,* P. D. Gupta,* R. B. Sutton,* M. N. Suzuki,* A. C. Thompson,* R. E. Coté, W. V. Prestwich, A. K. Gaigalas,† and S. Raboy†
Bull. Am. Phys. Soc. 13, 65 (January 1968)

HYPERFINE STRUCTURE OF LOW ATOMIC LEVELS OF La^{139}
W. J. Childs and L. S. Goodman
Bull. Am. Phys. Soc. 13, 20 (January 1968)

ISOMER SHIFTS OF Sb AND Sn IN SOLID SOLUTIONS OF THE Sb + Sn SYSTEM
C. W. Kimball (Metallurgy), Hugh Montgomery (Metallurgy), and S. L. Ruby
Bull. Am. Phys. Soc. 13, 123-124 (January 1968)

SIMPLIFICATION OF Ge(Li) SPECTRA BY CALCULATION
J. P. Marion, L. M. Bollinger, and G. E. Thomas
Bull. Am. Phys. Soc. 13, 51 (January 1968)

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*Carnegie-Mellon University, Pittsburgh, Pennsylvania.

†State University of New York, Binghamton, New York.

APS, Chicago (cont'd.)

EXCITED STATES OF As^{77} POPULATED IN THE 11-h DECAY OF Ge^{77}

D. A. McClure and H. H. Bolotin
Bull. Am. Phys. Soc. 13, 118 (January 1968)

NEUTRON PARTICLE-HOLE STATES IN THE EVEN-A BARIUM ISOTOPES

G. C. Morrison, N. Williams, J. A. Nolen, Jr., and D. von Ehrenstein
Bull. Am. Phys. Soc. 13, 70 (January 1968)

NEUTRON RADIUS OF Pb^{208}

J. A. Nolen, Jr., J. P. Schiffer, and N. Williams
Bull. Am. Phys. Soc. 13, 65 (January 1968)

PROTON-HOLE STATES IN Ar^{40} FROM THE $K^{41}(d,He^3)Ar^{40}$ REACTION

N. G. Puttaswamy and J. L. Yntema
Bull. Am. Phys. Soc. 13, 87 (January 1968)

ENERGY DEPENDENCE OF OPTICAL-MODEL PARAMETERS IN THE ELASTIC SCATTERING OF He^3 PARTICLES BY Ca^{40} AND Ni^{58}

B. W. Ridley,* T. W. Conlon,* and T. H. Braid
Bull. Am. Phys. Soc. 13, 117 (January 1968)

UNIMPORTANCE OF d ELECTRONS ON TIN ISOMER SHIFTS

S. L. Ruby, M. Wilson (Chemistry), and Hwa-Sheng Cheng†
Bull. Am. Phys. Soc. 13, 30 (January 1968)

OPTICAL-MODEL ANALYSIS OF PROTON ELASTIC SCATTERING FROM BORON AND BERYLLIUM

R. E. Segel, B. A. Watson, and P. P. Singh‡
Bull. Am. Phys. Soc. 13, 115 (January 1968)

ELASTIC SCATTERING OF ALPHA PARTICLES BY Si^{28}

P. P. Singh,‡ R. K. Li,‡ D. W. Devins,‡ J. W. Smith,‡ J. J. Kroepfl,‡ T. P. Marvin,‡ and A. J. Elwyn
Bull. Am. Phys. Soc. 13, 117-118 (January 1968)

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*A. E. R. E., Harwell, Didcot, Berks., England.

†Tsing-Hua University, Taiwan, China.

‡Indiana University, Bloomington, Indiana.

APS, Chicago (cont'd.)

ISOMER SHIFTS OF TIN IONS IN ICE
P. K. Tseng, S. L. Ruby, and Hwa-Sheng Cheng*
Bull. Am. Phys. Soc. 13, 30 (January 1968)

INELASTIC SCATTERING OF PROTONS BY B^{10}
B. A. Watson, J. J. Kroepfl,† P. P. Singh,† and R. E. Segel
Bull. Am. Phys. Soc. 13, 115 (January 1968)

COULOMB DISPLACEMENT ENERGIES OF THE NICKEL ISOTOPES
N. Williams, J. A. Nolen, Jr., J. P. Schiffer, and G. C. Morrison
Bull. Am. Phys. Soc. 13, 105 (January 1968)

GAMMA DECAY OF $T=\frac{3}{2}$ STATES IN Al^{25} AND P^{29}
D. H. Youngblood, G. C. Morrison, R. C. Bearse, and R. E. Segel
Bull. Am. Phys. Soc. 13, 85-86 (January 1968)

$Zn^{64,66,68,70}(d,He^3)$ REACTIONS AT 23.3 MEV
B. Zeidman and J. A. Nolen, Jr.
Bull. Am. Phys. Soc. 13, 105 (January 1968)

PHYSICS DIVISION INFORMAL REPORT

POLARIZATION AND NUCLEAR REACTIONS
J. E. Monahan
Physics Division Informal Report PHY-1968A (March 1968)

THESES

THE $Ge^{73}(n,\gamma)Ge^{74}$ GAMMA-RAY SPECTRUM AND ENERGY LEVELS OF Ge^{74}
Allen Paul Magruder
M.S. Thesis, Illinois Institute of Technology (January 1968)

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*Duquesne University, Pittsburgh, Pennsylvania.

†Indiana University, Bloomington, Indiana.

MÖSSBAUER EFFECT IN K^{40}
P. K. Tseng
Ph. D. Thesis, University of Michigan (1968)

STUDENT REPORTS

PHOTOIONIZATION OF O_2 WITH MASS SPECTROMETRIC ANALYSIS
Charles I. Gale
ACM student report to Lawrence University (December 1967)

TUNING CHARACTERISTICS OF A PLASMA-LOADED RADIOFREQUENCY COUPLED CIRCUIT
Paul McManamon
CSUI-ANL student report to John Carroll University, Cleveland, Ohio (Fall 1967)

V. PERSONNEL CHANGES IN THE ANL PHYSICS DIVISION

NEW MEMBERS OF THE DIVISION

University User of the ANL Tandem

Mr. Gary Gunther, Northwestern University. Lifetime measurements. First came to use the machine on 9 January 1968.

Student Aide

Mr. William J. Cosgrove, St. Procopius College, Lisle, Illinois. Working with M. Kaminsky on charge-transfer collisions of ions penetrating through monocrystalline metal films. Came to ANL on 6 February 1968.

Student Aides (ACM)

Mr. Donald Forsyth, Grinnell College, Grinnell, Iowa. Working with S. B. Burson on measurements of internal-conversion coefficients of neutron-capture transitions at the CP-5 reactor. Came to ANL on 18 March 1968.

Mr. Noel J. Petit, St. Olaf College, Northfield, Minnesota. Working with G. J. Perlow on Mössbauer investigation of paramagnetic effects in iridium compounds. Came to ANL on 5 February 1968.

Co-op Technician

Mr. Joseph E. Kulaga, Illinois Institute of Technology, Chicago, Illinois. Working with S. L. Ruby on study of antimony using the Mössbauer effect. Came to ANL on 15 February 1968.

CSUI-ANL Honor Students

Mr. Soltan Catto, New York Institute of Technology. Working with S. Cohen on nuclear theory. Came to ANL on 6 February 1968.

Mr. John M. Klebba, St. Benedict's College, Atchison, Kansas. Working with F. J. Lynch on measurements of the decay of scintillations. Came to ANL on 6 February 1968.

Mr. Louis A. Mole, John Carroll University, Cleveland, Ohio. Working with T. H. Braid on charged-particle detection methods. Came to ANL on 6 February 1968.

Mr. Lech Mync, New York Institute of Technology. Working with R. S. Preston on Mössbauer effect. Came to ANL on 6 February 1968.

Mr. Robert C. Schmitt, Western Illinois University. Working with L. Meyer-Schützmeister on angular distribution of the reaction $Al^{27}(He^{3},p)Si^{29}$. Came to ANL on 6 February 1968.

Mr. Philip G. Tomlinson, Indiana State University. Working with G. T. Wood on the six-gap beta-ray spectrometer. Came to ANL on 6 February 1968.

Mr. Frank E. Witter, Northern Illinois University, DeKalb, Illinois. Working with S. L. Ruby on the behavior of ions in ice. Came to ANL on 6 February 1968.

Mr. Thomas R. Wulff, Adrian College, Adrian, Michigan. Working with A. J. Hatch on impedance measurements in radiofrequency discharges. Came to ANL on 6 February 1968.

Mr. Warren M. Zander, Western Illinois University. Working with W. A. Chupka on photoelectron energy analysis. Came to ANL on 6 February 1968.

Technician

Mr. Robert J. Jedlowski joined the Physics Division on 5 February 1968 to work with Peter J. Billquist.

Secretary

Mrs. Marjorie Schmidt, returned to the Physics Division on 19 October 1967 as secretary to L. M. Bollinger.

PROMOTION

Mr. Peter J. Billquist was promoted to Chief Technician on 8 January 1968.

RETIREMENT

Dr. John J. Livingood came to Argonne as Associate Director of the Physics Division in September 1952, soon after he had completed the installation of the 60-in. cyclotrons at Brookhaven and Argonne. Both machines had been designed and constructed largely under his supervision while he was employed at the Collins Radio Company. After coming to ANL, he worked on the Fast Exponential Experiment, the Zero Power Reactor, and the proposals and preliminary development that led to the construction of the Zero Gradient Synchrotron. When the Particle Accelerator Division detached from the Physics Division on 2 April 1956, he became its director and served in that capacity throughout the design and early construction of the accelerator. On 1 September 1958 he returned to the Physics Division and has worked on plans for a 170-in. variable-energy cyclotron, the proposal to convert the present cyclotron into a 71-in. variable-energy cyclotron, the energy-analyzing system for the Argonne 60-in. cyclotron, and the theory of cyclic particle accelerators and of beam handling and focusing. He is the coauthor (with G. P. Harnwell) of Experimental Atomic Physics (McGraw-Hill Book Co., Inc., New York, 1933) and the author of Principles of Cyclic Particle Accelerators

(D. Van Nostrand Co., Inc., Princeton, New Jersey, 1961) and of Dispersive and Achromatic Magnet Systems (Academic Press, Inc., New York, to appear in fall 1968). He retired on 31 March 1968 but will continue the same type of work in the Physics Division.

DEPARTURES

Mr. Roy T. Moorehead, scientific technician, has been at Argonne since 1 July 1967. He terminated at ANL on 16 February 1968.

Mr. Eugene Schultz, chief technician, has been at Argonne since 11 May 1960. He terminated at ANL on 5 January 1968.

Dr. Poh-Kun Tseng, resident student associate (thesis) (OCUC affiliate) from the University of Michigan has been on the staff of the ANL Physics Division since 20 April 1967. He has worked on the Mössbauer effect in K^{40} and the Mössbauer effect on Sn VI ion in frozen solution. He terminated at ANL on 15 March 1968 to return to Physics Department, National Taiwan University, Taipei, Taiwan, Republic of China.

DECEASED

Mrs. Margaret Isom died on 12 March 1968 after a long illness. During her seventeen years at Argonne, Margaret held a number

of responsible positions. She was the secretary of John Livingood while he was Associate Director of the Physics Division, and later became the secretary of Louis Turner—both while he was Director of the Physics Division and when he became Deputy Director of the Laboratory. On his retirement, she returned to the Physics Division as the secretary of Lowell Bollinger.