ANL 6038
Physics and Mathematics
(TID-4500, 15th Ed.)
AEC Research and
Development Report

ARGONNE NATIONAL LABORATORY
P.O. Box 299
Lemont, Illinois

PHYSICS DIVISION
SUMMARY REPORT

July - August, 1959

Morton Hamermesh, Division Director

Preceding Summary Reports:

ANL-5955 - December, 1958 - January, 1959
ANL-5978 - February - April, 1959
ANL-6020 - May - June, 1959

August, 1959

Operated by The University of Chicago
under
Contract W-31-109-eng-38

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FOREWORD

The Summary Report of the Physics Division of the Argonne National Laboratory is issued monthly for the information of the members of the Division and a limited number of other persons interested in the progress of the work. Each individual project reports about once in 3 months, on the average. Those not reported in a particular issue are listed separately in the Table of Contents with a reference to the last issue in which each appeared.

This is merely an informal progress report. The results and data therefore must be understood to be preliminary and tentative.

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

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I. EXPERIMENTAL NUCLEAR PHYSICS11-22   Installation and Operation of the Van de Graaff Generator   (5220)
                  Jack R. Wallace

This report covers the operation of the Van de Graaff generator in the Physics Division for the period April 1 to June 30, 1959, inclusive.

The generator was used to accelerate protons, deuterons, and alpha particles. The generator voltage was from 900 kev to 4.2 Mev. Beam currents measured at the target varied from 0.1 microampere to 30 microamperes.

The following list shows the division of time and types of experiments being performed with the Van de Graaff generator by the group. No effort has been made to show any efficiency factor for the use of the allotted time given to the various experimenters.

1. $N^{14}(p,\gamma)O^{15}$	Lee, Meyer, Vincent	90.2 hr
2. Gamma-ray studies on $F^{19}(p,\alpha\gamma)O^{16}$	Huizenga, Raboy, Trail	163.1
3. Proton polarization	Schiffer, Smither	108.7
4. Total neutron cross sections in the kev region	Hibdon	128.5
5. (p,γ) studies of many nuclei	Lee, Meyer, Raboy, Schiffer, Trail, Vincent	345.2
6. Lifetimes of excited states by pulsed-beam technique	Holland, Lynch	118.0
7. Total cross-section studies	Lee, Mooring, Lane	116.4
8. Calibration check on counter	Perlow	5.0

9. Half-life measurements	Lee, Meyer, Vincent	29.3
	Total	1104.4
Start-up and daily maintenance		45.5
Machine repairs and experimental setup		210.1
Total time available [65 days $\times$ 16 hr + 26 days $\times$ 8 hr + 14 days $\times$ 8 hr (midnight shift)]		1360.0 hr

Bearing failure in various components of the Van de Graaff generator has been quite high. This short life of bearings could be caused by a number of things such as: (1) Breakdown of lubrication—possibly caused by gases used or formed in the generator. (2) Inadequate cooling. (3) Presence of high electric fields. (4) Improper bearing tolerance. (5) Bad choice of bearings for intended job.

A bearing specialist was called in to discuss these problems. Each component that had bearing failure was examined for evidence to indicate what might be causing the failure. Number four of the above list seemed to be the answer in all cases. A different lubricant was recommended also. The machine shop made the suggested changes on the respective bearing tolerances. No further bearing failure has occurred to date.

The bearings of the 15-hp motor driving the belt failed most frequently. Upon examination it was found that the motor manufacturer had violated several sound practices recommended by bearing manufacturers. A temporary correction was made, but a new motor from a different manufacturer seemed desirable. A new motor has been bought and installed and no further bearing failure has occurred to date.

Work is still being done in an effort to extend the life of the charging belt. A new belt manufacturer has been found and a different type of belt ordered that might be an improvement on the type of belt now being used.

12-5   Integrator of Current in an Ion Beam   (5220)

Frank Lynch and Alexander Langsdorf, Jr.
Reported by Frank Lynch

A technical report describing the integrator appeared in Rev. Sci. Instr. 30, 276-279 (April 1959). This terminates the project.

98-22   Neutron Total Cross Sections in the Kev Region   (5220)

Carl T. Hibdon

MEASUREMENTS OF SODIUM

The study of the nuclear levels of Na^{24} has been continued by use of the same techniques and sodium samples described previously.¹ During previous measurements it was found that the widths of many of the levels are too small to be resolved sufficiently by flat detection to determine their parameters. It was found that these peaks could be resolved better by self-detection and hence their parameters could be more reliably determined. Therefore, the latest measurements were devoted almost entirely to self-detection. Most of the peaks up to 350 kev have been studied by this method and an analysis of these peaks is in progress. The analyses have been completed in the region from about 180 to 350 kev and are given in the following sections. To date a total of 127 peaks have been observed up to 500 kev.

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¹ Physics Division Summary Report, ANL-5978 (Feb. - April, 1959), p. 14.

A. Analysis of the Resonance Levels from 180 to 240 kev

The large resonance observed by Stelson and Preston² just above 200 kev was found to be composed of two peaks, Nos. 42 and 43, shown in the upper curve of Fig. 1 in which points obtained by self-detection are represented by solid circles and those obtained by flat detection are represented by open circles. The splitting of this resonance into two peaks was observed twice by flat-detection measurements and later by self-

Fig. 1. Neutron total cross section (upper curve) of sodium from 180 to 240 kev. Open circles show data obtained by flat detection; solid circles, data by self-detection. Curve A is a single-level plot for resonance No. 42 and includes the low-energy wing of No. 49 and the s-wave levels at higher energy. Curve B represents the difference between the data and curve A.

detection. The combined configuration of these two peaks together with the overlapping wings of other nearby peaks indicates that No. 42 can be expected to be a relatively narrow p- or d-wave resonance. The high value of the cross section in the high-energy wing of Nos. 42 and 43 indicates an s-wave neutron interaction for No. 43. By trial and error it was found that the most reasonable fit for Nos. 42 and 43 could be obtained only by assuming No. 43 to be an s-wave resonance. Resonance No. 42 is then located at the minimum of No. 43 and hence this minimum depresses the peak of No. 42 and also distorts the shape of the resonance. This distortion is clearly recognizable in Fig. 1. Repeated attempts to analyze this pair of resonances indicated that a best fit could be obtained by tak-

ing a value of $J = 3$ for No. 42 with $\Gamma = 1.8$ kev and $l = 1$, although a value of $l = 2$ can not be unambiguously ruled out. After the analyses were completed, the self-detection data near the peak of No. 42 were corrected for the depression caused by the minimum of No. 43. The corrected points are represented by crosses in the upper curve of Fig. 1. The highest corrected point is then very near the possible value for $J = 2$ and rules out this value of J because a resonance of this width can not be expected to be resolved to a height so near its true value. Curve A in Fig. 1 includes the potential scattering, the combined single-level plots of No. 42 and No. 49 ($J = 2$, $l = 1$), the s-wave level No. 60, and the level at 542 kev. The wings of the s-wave levels, which were computed by the multiple-level dispersion formula, show that the cross section is depressed throughout this region. By subtracting curve A from the data in Fig. 1, one obtains the two parts of curve B, which are then transferred to curve D of Fig. 2.

Because of its apparent asymmetrical shape and on the basis of the trial-and-error fit mentioned above, peak No. 43 is taken to be an s-wave resonance. The measured peak height is close to the theoretically possible height for $J = 1$. Use of smaller neutron energy spreads would not be expected to resolve a resonance of this apparent width to any appreciably higher peak value. Therefore it is considered well resolved

Fig. 2. Analysis of the resonances in the region from 180 to 240 kev. Curve C shows the multiple-level s-wave plot for Nos. 43 and 50. Curve E is a single-level plot for No. 48. Curve D from 180 to 200 kev has been corrected for the low-energy wings of resonances Nos. 43 and 48. The potential scattering is not included in any curve.

Fig. 3. Analysis of the resonances from 176 to 230 keV. The potential scattering and the wings of s-wave levels were removed by the subtractions shown in Figs. 1 and 2. The dashed single- and multiple-level plots show the best fits for the resonances.

48, it is also taken to be an s-wave resonance. Its relatively narrow width prevents one from resolving its peak to a height sufficient to distinguish clearly between the two possible values of 1 and 2 for J . But the degree to which it is resolved, particularly by self-detection, shows a preference for a value of $J = 2$. Moreover, one can account for the high-energy wing of this resonance more easily with a value of $J = 2$. By trial and error it was found that a best fit occurs for a width of 0.90 keV. The single-level plot for the parameters $J = 2$, $\Gamma = 0.90$ keV and $l = 0$ is shown as curve E in Fig. 2. Curves C and E are then subtracted from the data to obtain the two parts of curve F in Fig. 3.

All of the peaks in the group comprising Nos. 44 to 47 inclusive (Fig. 3) appear to be symmetrical in shape so they are taken to be p- or d-wave resonances. The fairly deep minimum (revealed by self-detection) between Nos. 44 and 45 is indicative of mutual interference

and J has a value of 1. Curve C in Fig. 2 is a multiple-level plot of the s-wave levels Nos. 43 and 50, obtained by the parameters shown in Table I. These parameters were first obtained by trial and error and later confirmed by the computer GEORGE. The mutual interference of these two levels lowers the peak height of No. 43 below the single-level height and elevates the peak of No. 50 above its single-level height as shown by curve C in Fig. 2 and curve E in Fig. 5.

Because of the asymmetrical shape of peak No.

between this pair of resonances, and the same is true for Nos. 46 and 47. In view of these minima and the relative observed heights of these peaks, it is unlikely that all four peaks are attributable to the same value of J . Mutual interference is not indicated between Nos. 45 and 46 because they are far enough apart that a deep minimum would have been observed if present. The self-detection data indicate a value of $J = 2$ for Nos. 44 and 45 and a value of $J = 1$ for Nos. 46 and 47. The multiple-level plots shown in Fig. 3 were obtained by use of the parameters shown in Table I. These plots do not fully account for the various minima but are about as compatible with the various aspects of the data as one can expect. The deep minima shown by the multiple-level plots are not resolved to that extent experimentally because (a) the valleys as well as the peaks are too narrow to be fully resolved, and (b) overlapping wings of neighboring resonances elevate these minima above what is shown by the multiple-level plots, and (c) one can not rule out the possibility of the presence of other narrow unresolved resonances.

In the region below 200 kev one finds no indications of s-wave resonances. The observed peak heights of Nos. 37 and 38 are higher than the theoretical value for $J = 0$, but they are wide enough that their peaks would be expected to be considerably higher if J were to be 1. Moreover, the overlapping wings of other near-by levels elevate the peaks somewhat. Further, the minimum between these peaks indicates mutual interference. This will elevate both peaks above their single-level height. Therefore, J is taken to be 0 for both resonances. Their widths indicate a value of $l = 1$. The multiple-level plot of Nos. 33 through 38 inclusive, obtained by a width of 1.9 kev for No. 37 and a width of 2.1 kev for No. 38, is shown in Fig. 3. This plot accounts very well for these two peaks. The value of J is taken to be 1 for peaks Nos. 39 to 41 inclusive because of their approximately equal peak heights. The apparent widths of these levels are too narrow to resolve to their true peak heights but sufficiently wide that one would have resolved the peaks to greater heights

TABLE I. Summary of the levels of Na^{24} from 175 kev to 350 kev derived from neutron reactions with Na^{23} . The parameters J, Γ_n and l are probable values obtained as a best fit to the data. The quantity γ_l^2 is the reduced width obtained by the relation $\Gamma_n = 2P_l \gamma_l^2 \cdot E_r$, Γ_n and γ_l^2 are expressed in kev.

No.	E_r	J	Γ_n	l	γ_0^2	γ_1^2	γ_2^2
37	178.4	0	1.9	1		24.1	
38	182.6	0	2.1	1		25.8	
39	188.0	1	1.6	1		18.9	
40	193.0	1	1.2	2(1)		13.6	837
41	196.7	1	1.1	2(1)		12.2	735
41A	199.5	2	0.7	2		7.6	450
42	202.7	3	1.8	1		19.2	1119
43	205.2	1	3.6	0	4.7		
44	213.7	2	1.3	1(2)		12.9	706
45	218.2	2	1.2	1(2)		11.6	621
46	224.0	1	1.7	1(2)		15.8	825
47	227.7	1	1.7	1(2)		15.4	795
48	231.9	2	0.90	0	1.1		
49	242.0	2	6.0	1		50.2	
50	246.3	1	3.0	0	3.57		
51	255.0	2	1.3	2		10.6	422
52	260.5	1	1.7	2(1)		12.5	548
53	264.7	1	0.9	2		6.7	291
54	268.5	2	1.1	2			329
55	272.8	1	1.1	2		7.8	328
56	278.5	1	1.3	2			363
57	287.0	1	1.3	2			345
58	290.7	2	0.9	2			230
59	294.7	1	1.3	2			323
59A	298.0	0	2.0	2			473
60	302.5	2	2.5	0	2.7		
61	306.5	0	1.6	2		9.8	362
62	311.6	1	1.5	2		8.9	326
63	316.5 ⁰	2	0.9	3(2)			188
63A	321.0	1	0.9	3(2)			182
64	324.0	1	1.3	2		7.4	257
64A	326.8	1	0.9	3(2)			175
65	330.8	1	2.0	2		11.0	376
65A	334.2	1	1.0	3(2)			183
66	338.3	1	1.7	2		9.1	300
67	343.6	2	1.0	3(2)			174
67A	346.0	1	0.75	3(2)			128

for a value of $J = 2$. The minimum between Nos. 39 and 40 is not as deep as would be expected if there was mutual interference between resonances as well separated as these. On the other hand, mutual interference is assumed for peaks Nos. 40 and 41 because of the deep minimum between them. The self-detection data show that peak No. 41A is high and narrow with $J \geq 2$. Because of the nature of the data presented by the foregoing arguments, one must then necessarily assign a value of $\ell = 1$ to No. 39 and $\ell = 2$ to Nos. 40, 41 and 41A. The various plots obtained by the widths tabulated in Table I are shown in Fig. 3 and the sum of the plots appears to agree with the data except near the peaks.

B. Analysis of the Resonance Levels from 240 to 290 kev

Two different measurements were made by flat detection over the region of peaks Nos. 49 and 50. The data are shown in the upper curve of Fig. 4, the points obtained in one run being represented by open circles and those of a second run by crosses. Resonance No. 49 is the predominant peak of this region and is the widest observed peak up to 500 kev. The wings are sufficiently revealed to show that it is symmetrical in shape. Because of its large width, it is attributable to a p-wave neutron interaction. Also because of its large width, this resonance is undoubtedly

Fig. 4. Neutron total cross section (upper curve) of sodium from 230 to 290 kev. Open circles show data obtained by flat detection; solid circles, data by self-detection. Curve A is a single-level plot for resonance No. 49. It includes the high-energy wing of No. 42 and the wings of s-wave levels at higher energy. Curve B represents the difference between the data and curve A.

Fig. 5. Analysis of the resonances in the region from 230 to 290 keV. Curve E shows the multiple-level s-wave plot for resonances Nos. 43 and 50. Curve C has been corrected for the low-energy wing of resonance No. 50. The potential scattering is not included in any curve.

includes a single-level calculation of the high-energy wing of No. 42 and also the low-energy wing of the s-wave level No. 60 and of the s-wave resonance at 542 keV. The low-energy wings of these s-wave levels were calculated from the multiple-level formula. The two parts of curve B in Fig. 4 were obtained by subtracting curve A from the data and were then transferred to Fig. 5 where they are labeled C and D. The analysis of resonance No. 48 is shown in Fig. 2.

With any reasonable widths of the resonances in the neighborhood of peak No. 50, subtracting their wings from the data yielded an asymmetric shape for the latter peak. In particular, the cross section in the high-energy wing of No. 50 is so high that an s-wave neutron interaction seems to provide the only possible means of accounting for it. Because of its width, this resonance is nearly completely resolved and the value of J is therefore taken to be 1. Curve E in Fig. 5 is a multiple-level plot of the s-wave resonances Nos. 43 and 50 and is a continuation of curve C in Fig. 2.

well resolved and a value of $J = 2$ appears to be certain. It is to be noted, however, that the low-energy wings of the s-wave level No. 60 and the one at 542 keV extend into this region and therefore depress the cross section everywhere in the region. Consequently the apparent peak height of resonance No. 49 should fall below the theoretical single-level value for $J = 2$ even with perfect resolution. The curve designated by A in Fig. 4 is a single-level plot obtained with a width of $\Gamma = 6.0$ keV and $l = 1$. It

It is understandable that resonance No. 49, although 6 kev wide, is not resolved to its true single-level peak height for a value of $J = 2$. This is attributable in part to the depression of the cross section in this region by the s-wave levels at higher energies and in part to the fact that No. 49 is located very near the minimum of No. 50; but this extra depression caused by the minimum of No. 50 is mostly offset by the high-energy wing of the s-wave resonance No. 48 and the wings of other neighboring resonances. The calculated curve A in Fig. 4 includes the wing of the s-wave resonance No. 60 and of the one at 542 kev plus the high-energy wing of No. 42. The peak height of this curve can be seen to be a few tenths of a barn below the single-level height of No. 49. The close agreement of the calculated and observed peak heights of No. 49 then serves to indicate that the assumed value of the potential scattering cross section in this region is close to its true value. Resonance No. 50, having a width of 3 kev, might also be expected to be resolved very nearly to its true peak height but one sees in Fig. 5 that it is slightly below the multiple-level value. However, the multiple-level plot (curve E in Fig. 5 has not been corrected for the wings of neighboring resonances and therefore will be slightly higher than the observed peak height of No. 50.

By subtracting curve E in Fig. 5 from curve D one obtains the curve shown in Fig. 6. All of the peaks in this group (Nos. 51 through 59A) appear to be symmetrical in shape and are, therefore, attributable to p- and

Fig. 6. Analysis of the resonances from 250 to 300 kev. The potential scattering and wings of s-wave levels were removed by the subtractions shown in Figs. 4 and 5. The dashed single- and multiple-level plots show the best fits for the resonances.

d-wave neutron interactions. The various single- and multiple-level plots shown in Fig. 6 were obtained by use of the parameters tabulated in Table I. These parameters were determined by trial and error. Peak No. 56A is a spurious reflection of the 2.95-keV resonance and arises because of the second group of low-energy neutrons in the beam.³ This peak is therefore not included among the levels of Na^{24} .

C. Analysis of the Resonance Levels from 290 to 350 keV.

The data for this region are shown by the upper curve in Fig. 7, where open circles represent points obtained by flat detection and closed circles the points obtained by self-detection. Peak No. 60 is

Fig. 7. Neutron total cross section (upper curve) from 288 to 348 keV. Open circles show data obtained by flat detection; solid circles, data by self-detection. Curve A is the multiple-level s-wave plot of resonance No. 60 and the s-wave level at 542 keV. It also includes the multiple-level plot of resonances Nos. 43 and 50. Curves B and C were obtained by subtracting curve A from the data.

the predominant resonance in this region and clearly shows a pronounced minimum on its low-energy side. Its shape, although modified to some extent by neighboring peaks, is still distinctly asymmetrical and therefore is clearly attributable to an s-wave neutron interaction. The observed peak height is 5.5 barns (including the potential scattering) compared with theoretical single-level heights of 4.6 and 6.4 barns for $J = 1$ and 2, respectively. Mutual interference with the s-wave resonance at 542 keV can be expected to reduce the peak height of No. 60 considerably because of the large width of the

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C. T. Hibdon, Phys. Rev. 108, 414 (1957); 114, 179 (1959).

former. Therefore, the value of J is taken to be 2. By a direct examination, one can see that the width is approximately 2.5 kev. This was confirmed by a multiple-level plot for this resonance and the resonance at 542 kev. This plot is shown by curve A in Fig. 7, which also includes the contribution of the multiple-level plot of resonances Nos. 43 and 50 ($J = 1$, $l = 0$). By subtracting this curve from the data, one obtains curves B and C. Only curve C is then transferred to Fig. 8, curve B being included in Fig. 6. Peak No. 61 is attributable to $J = 0$ and a single-level plot for $\Gamma_n = 1.6$ kev and $l = 2$ is shown by curve D in Fig. 7, this being about the best fit in view of the wings of the neighboring levels.

No wide peaks or s-wave resonances are left in the region from 300 to 350 kev. The peak heights obtained by self-detection for the first four peaks indicate that no peak has a value of J less than 1 and the relatively narrow widths indicate d- and f-wave neutron interactions. The observed peak height of No. 63 (self-detection) is near the possible value for $J = 1$ and, for a resonance of this apparent width, one could expect by use of smaller neutron energy spreads to resolve this peak to a considerably higher value which would be at least sufficiently high to rule out a value of $J = 1$. Since the flat-detection data show similar heights and widths for Nos. 63 and 67, the value of J is taken to be 2 for these two resonances. Peaks Nos. 62, 64, 65 and 66 are then

Fig. 8. Analysis of the resonances from 306 to 350 kev. The potential scattering and wings of s-wave levels were removed by the subtraction shown in Fig. 6. The best fit is shown by the dashed curves obtained by the appropriate single- and multiple-level computations.

attributable to $J = 1$ because they are wider than Nos. 63 and 67 and their peaks are not as high (self-detection). The self-detection data on peak No. 63A also indicate a value of $J = 1$ for this peak and it is then reasonable to conclude the same for Nos. 64A, 65A and 67A. These latter peaks are so narrow that the value of l is 2, or preferably 3, for them. The appropriate single- and multiple-level plots are shown in Fig. 8. Single-level plots are shown for Nos. 63 and 67 for $l = 3$ and a single-level plot is shown for Nos. 62, 64, 65 and 66 for $l = 2$. A multiple-level plot is shown for Nos. 63A, 64A, 65A and 67A ($l = 3$). Although this multiple-level plot was obtained for $l = 3$, it differs little from the one obtained for $l = 2$. These plots were obtained by use of the parameters shown in Table I. The widths were determined by trial and error. The widths of these resonances are relatively narrow and it is entirely possible that one or more of them could be resolved to higher values of J by appropriate neutron energy spreads. On the other hand, their widths are sufficiently wide that one can hardly expect to resolve them to heights much above those heights corresponding to the assigned values of the J 's. The corresponding reduced widths are so small that one expects that $l \geq 2$ for Nos. 61, 62, 65 and 66 and $l = 3$ for all others.

PAPERS

A. A paper entitled "Distribution of the Angular Momenta, Level Spacings and Neutron Widths of Al^{28} " has been published in the Physical Review. [Phys. Rev. 114, 179 (1959)].

B. A paper entitled "Distribution of Angular Momenta of Resonance Levels for Neutron Scattering" appeared in the Proceedings of the Second International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958. (United Nations, Geneva, 1959), Vol. 15, p. 72.

C. A paper entitled "Thermal Neutron $\bar{\nu}$ for Pu^{24} " by Arthur H. Jaffey, Carl T. Hibdon, and Ruth Sjoblom has been accepted for publication in the Journal of Nuclear Energy.

II. MASS SPECTROSCOPY

38-10   Mass Spectrometric Studies of Charged Atomic and Molecular Products of Nuclear Transformation (5220)

G. R. Anderson and S. Wexler
Reported by S. Wexler

A. BOND RUPTURE OF $\text{DBr}^{80\text{m}}$ FOLLOWING NUCLEAR ISO- MERIC TRANSITION

When 4.4-hr. $\text{Br}^{80\text{m}}$ undergoes isomeric transition, its 18-min daughter may be expected to receive a high positive charge. The transition occurs by internal conversion with loss of electrons by conversion and Auger cascades. A mean charge of +10e has been measured¹ by direct current methods for the products from decay of $\text{C}_2\text{H}_5\text{Br}^{80\text{m}}$. Snell and Pleasonton,² using mass spectrometric techniques, have shown that when $\text{Xe}^{131\text{m}}$ decays by internal conversion, a peaked distribution of charged daughter ions results, the charges ranging from +1 to +22. The average charge is found to be +7.91 e in good agreement with the value of +8.5e measured by Perlman and Miskel.³

If the radioactive $\text{Br}^{80\text{m}}$ is attached to deuterium prior to the transformation, the question arises whether the immediate daughter ion DBr^{80} can survive dissociation when it has a high positive charge. Several investigators have addressed themselves to this problem. Hamill and

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¹ S. Wexler, Phys. Rev. 93, 182 (1954).

² A. H. Snell and F. Pleasonton, Proc. Roy. Soc. (London) A241, 141 (1957).

³ M. L. Perlman and J. A. Miskel, Phys. Rev. 91, 899 (1953).

Young⁴ found that about 15% of the DBr^{80} remain bound, while about 25% of the HBr^{80} are undissociated when tagged hydrogen bromide is the gas. More recently, Luebbe and Willard⁵ remeasured the extent of bond rupture in $\text{HBr}^{80\text{m}}$ and found it to be 93%. However, both experiments were done with gases at high pressures, wherein collisions and dissociation by charge neutralization processes may contribute to break-up of the diatomic molecule. Theoretical arguments of Magee and Gurnee⁶ suggest that highly charged $(\text{HBr})^{+n}$ species may be stable. But Johnston and Arnold⁷ failed to detect HBr ions of charge +3 and +4 by electron impact in a mass spectrometer, although HBr^{1+} and HBr^{2+} were observed.

In order to resolve the problem directly by observations on isolated molecules undergoing isomeric transition, $\text{DBr}^{80\text{m}}$ of high specific activity has been introduced at low pressure into the improved model of the mass spectrometer for radioactive gases. The relative intensities of Br and DBr of a given charge were measured. In preliminary findings Br^{+n} was observed with n ranging from +1 to +10, while the ratio $\text{DBr}^{+n}/\text{Br}^{+n}$ was less than 0.05 for $n = 3$ through 10; and $\text{DBr}^{+2}/\text{Br}^{+2}$ was 1.4 ± 0.2 . The intensities of the singly-charged species were found to be obscured by self-radiation of the bulk gas by active material deposited on the walls of the source volume. No D^+ ions were detected.

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⁴ W. H. Hamill and J. A. Young, J. Chem. Phys. 20, 888 (1952).

⁵ R. H. Luebbe, Jr., and J. E. Willard, J. Chem. Phys. 29, 124 (1958).

⁶ J. L. Magee and E. F. Gurnee, J. Chem. Phys. 20, 894 (1952).

⁷ W. H. Johnston and J. R. Arnold, J. Chem. Phys. 21, 1499 (1953).

B. DISSOCIATION OF $1,2\text{-C}_2\text{H}_4\text{Br}^{80\text{m}}$ BY INTERNAL CONVERSION

Further studies of the fragmentation of $1,2\text{-C}_2\text{H}_4\text{Br}^{80\text{m}}$ by nuclear decay were made. The fragmentation pattern observed was similar to that obtained earlier⁸ with the original design of the spectrometer. In addition to several fragments containing carbon, a spectrum of charged Br ions was found ranging from +1 to about +15. The peak in the distribution was at approximately +6.

C. MODIFICATION OF THE MASS SPECTROMETER FOR RADIOACTIVE GASES

The original spectrometer was dismantled and decontaminated. An improved model was constructed which eliminated the electrostatic deflector and provided more efficient pumping of the detector. A new source volume, detector chamber, and inlet line were installed.

Electrical leads for each of the guide rings of the cone were brought in through Kovar seals welded into the back flange. The voltage on each ring can be varied over a wide range by means of a 10-turn Helipot. A profile sketch of the modified spectrometer appears in Fig. 9.

Fig. 9. Mass spectrometer for radioactive gases.

⁸ S. Wexler, Physics Division Summary Report ANL-5786 (July-September 1957), pp. 79-81.

III. CRYSTALLOGRAPHY

4-1

Crystal Structure Studies of Compounds of Elements Ac—Am
(5230)

H. A. Plettinger and W. H. Zachariasen
Reported by W. H. Zachariasen

THE CRYSTAL STRUCTURE OF SODIUM URANYL ACETATE

Sodium uranyl acetate, $\text{NaUO}_2(\text{O}_2\text{CCH}_3)_3$, is cubic with space group P2_13 and $a = 10.688 \pm 0.002$ Å. The positions of all atoms were deduced from precisely measured x-ray diffraction intensities. In the collinear uranyl group, $\text{U} - \text{O} = 1.71 \pm 0.04$ Å. Normal to the uranyl axis are six secondary bonds from uranium to acetate oxygens with $\text{U} - \text{O} = 2.49 \pm 0.02$ Å. Sodium is bonded to six acetate oxygens with $\text{Na} - \text{O} = 2.37 \pm 0.04$ Å. The bond lengths within the acetate group are $\text{C} - \text{C} = 1.52 \pm 0.05$ Å, $\text{C} - \text{O} = 1.25 \pm 0.05$ Å and 1.28 ± 0.04 Å, and 121° is found for the carboxyl bond angle. A revised bond length vs bond strength curve for $\text{U}^{\text{VI}} - \text{O}$ bonds is presented.

Earlier studies of the crystal structure of uranyl salts have given some information about the crystal chemistry of these compounds. It has been shown that the uranium atom, in addition to the two strong uranyl bonds, forms four, five or six secondary bonds to oxygen or fluorine atoms. The positions of the light atoms have been determined with precision only for a small number of structures; but it was found that the lengths of the primary as well as of the secondary bonds varied considerably from compound to compound. This variation has been correlated with corresponding variation

in the bond strengths.¹ However, the published empirical bond length vs bond strength curve was based upon a small number of observations, and the present investigation was undertaken in the hope of obtaining further reliable experimental results.

The crystal structure of sodium uranyl acetate, $\text{NaUO}_2(\text{O}_2\text{CCH}_3)_3$, was first studied by I. Fankuchen.² He reported the space group $P2_13$ and four molecules in a unit cube with $a = 10.670 \pm 0.001$ kX. Fankuchen described a complete structure; but only the uranium and sodium positions were deduced from the observed intensities. However, this early work gave the important result that the uranyl radical, by space group symmetry, had to be collinear.

The isostructural neptunium and plutonium compounds were identified during the war.³ A unit cube of $a = 10.659 \pm 0.002$ kX was reported for the neptunium and of $a = 10.643 \pm 0.002$ kX for the plutonium compound. The analogous americium compound has since been added to the isostructural series.⁴

EXPERIMENTAL PROCEDURE

The structure analysis of MgUO_2O_2 ⁵ and of $\text{K}_3\text{UO}_2\text{F}_5$ ⁶ demonstrated that it is possible by x-ray diffraction methods to locate the positions of light atoms in the presence of uranium to an accuracy of 0.03 Å. In order to reach this precision it is necessary to measure intensities with an accuracy attainable only with counters and to correct accurately for absorption and extinction effects.

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¹ W. H. Zachariasen, Acta Cryst. 12, 795 (1954).

² I. Fankuchen, Z. Kristallogr. 91, 473 (1935).

³ W. H. Zachariasen, Acta Cryst. 2, 388 (1949).

⁴ F. H. Ellinger, Private communication (1956).

⁵ W. H. Zachariasen, Acta Cryst. 12, 788 (1954).

⁶ W. H. Zachariasen, Acta Cryst. 12, 783 (1954).

Crystals were prepared by slow evaporation from a solution of uranyl nitrate and sodium acetate in molar proportions. Most of the crystals so obtained were found unsuitable for intensity measurements, since the x-ray showed a seemingly single crystal to consist of two or more individuals in slight misalignment. However, two excellent specimens were eventually found, and these were made into nearly perfect spheres in the Bond sphere grinder. The radii of the two spheres were 0.0116 ± 0.0002 cm and 0.0122 ± 0.0003 cm, where the limits of error denote the extreme variation.

The intensity measurements were carried out with a General Electric XRD spectrometer rebuilt for single-crystal work and using filtered CuK radiation and a proportional counter. The intensities of all possible HKO reflections were measured. Because of the very high absorption ($\mu = 470 \text{ cm}^{-1}$), very small departures from perfect spherical shape give rise to large intensity differences for equivalent reflections. In extreme cases it was found that the intensity could vary by as much as 30% from one equivalent plane to another, while intensity measurements for a given plane were reproducible to 2%. In order to minimize this source of error, measurements were made for all planes of the same crystallographic form and the average was taken. As a means of further reducing the experimental errors, complete HKO data were obtained for both crystal spheres described above. When the intensities were reduced to structure factors, there was nearly perfect agreement between the two sets of complete data.

THE RESULTS

The complete structure was deduced in a direct manner with the aid of the "heavy atom technique."

In agreement with Fankuchen's early work, it was found that

$a = 10.688 \pm 0.002$ Å with four molecules per unit cell and space group $P2_13$. The positions of this space group are:

$$\begin{aligned}
 4a \quad & (x, x, x) \quad ; \quad \left(\frac{1}{2} + x, \frac{1}{2} - x, \bar{x}\right) \curvearrowright \\
 12b \quad & (x, y, z) \curvearrowright \quad ; \quad \left(\frac{1}{2} + x, \frac{1}{2} - y, \bar{z}\right) \curvearrowright \quad ; \quad \left(\frac{1}{2} + y, \frac{1}{2} - z, \bar{x}\right) \curvearrowright \quad ; \\
 & \left(\frac{1}{2} + z, \frac{1}{2} - x, \bar{y}\right) \curvearrowright.
 \end{aligned}$$

The uranium atoms, the sodium atoms and the uranyl oxygen atoms (O_I and O_{II}) are in positions 4a. All the other atoms are in the general positions 12b. The atomic coordinates are as given in Table I.

TABLE I. Atomic coordinates in sodium uranyl acetate.

		Fankuchen ²	This study
U	x	0.428 ± 0.002	0.4292 ± 0.0003
Na	x	0.81 ± 0.03	0.8289 ± 0.0006
O_I	x	0.31 ± 0.02	0.336 ± 0.002
O_{II}	x	0.55 ± 0.02	0.521 ± 0.002
O_{III}	x		0.382 ± 0.002
	y		0.291 ± 0.001
	z		0.608 ± 0.001
O_{IV}	x		0.551 ± 0.001
	y		0.241 ± 0.001
	z		0.500 ± 0.002
C_I	x		0.482 ± 0.001
	y		0.229 ± 0.002
	z		0.598 ± 0.001
C_{II}	x		0.509 ± 0.002
	y		0.118 ± 0.002
	z		0.683 ± 0.001

TABLE II. Lengths of the bonds formed by the atoms
in sodium uranyl acetate.

U - 1 O _I = 1.72 ± 0.04 A	O _I - 1 U = 1.74 ± 0.04 A
- 1 O _{II} = 1.70 ± 0.04 A	
- 3 O _{III} = 2.47 ± 0.02 A	O _{II} - 1 U = 1.70 ± 0.04 A
- 3 O _{IV} = 2.51 ± 0.02 A	O _{III} - 1 U = 2.47 ± 0.02 A
Na - 3 O _{III} = 2.39 ± 0.04 A	- 1 Na = 2.39 ± 0.03 A
- 3 O _{IV} = 2.36 ± 0.04 A	- 1 C _I = 1.26 ± 0.05 A
C _I - 1 C _{II} = 1.52 ± 0.05 A	O _{IV} - 1 U = 2.51 ± 0.02 A
- 1 O _{III} = 1.26 ± 0.05 A	- 1 Na = 2.36 ± 0.04 A
- 1 O _{IV} = 1.28 ± 0.04 A	- 1 C _I = 1.28 ± 0.04 A
O _{III} - C _I - O _{IV} ≈ 121°	
C _{II} - 1 C _I = 1.52 ± 0.05 A	
- 1 H _I = 1.1 (0.8) A	
- 1 H _{II} = 1.0 (1.5) A	
- 1 H _{III} = 1.0 (1.1) A	

The lengths of the bonds formed by the various atoms in the structure are given in Table II. The configuration about a uranium atom is shown in Fig. 10.

Fig. 10. The configuration about a uranium atom and within the acetate group, as seen along a three-fold axis. The uranium atom lies in the projection plane. Numbers in parentheses give the height in Å above this plane.

This has been reported by W. H. Zachariasen and H. A. Plettinger, *Acta Cryst.* 12, 526-530 (July 1959).

10-1

The Crystal Structure of Li_2WO_4

(5230)

H. A. Plettinger and W. H. Zachariasen
Reported by W. H. Zachariasen

This compound is rhombohedral with six molecules in the unit cell. The dimensions of the rhombohedral unit cell are $a = 8.888 \pm 0.002 \text{ Å}$, $\alpha = 107.78 \pm 0.03^\circ$. The dimensions of the corresponding hexagonal cell with 18 molecules are $a = 14.361 \text{ Å}$, $c = 9.602 \text{ Å}$.

A precise determination of all atomic positions is under way.

V. THEORETICAL PHYSICS, GENERAL

- 15-9   Statistical Properties of Nuclear Energy States (formerly
"Energy-Level Density of a System of Fermi Particles") (5220)
N. Rosenzweig and C. E. Porter*
Reported by N. Rosenzweig

Through the kind cooperation of D. R. Inglis, the following paper was presented at the Honolulu meeting of the American Physical Society, August, 1959.¹

STATISTICAL PROPERTIES OF ATOMIC ENERGY STATES

Ever since the discovery of the phenomenon of neutron resonance and its explanation in terms of the "quasi-stationary" states of the compound nucleus, attempts have been made to discover the statistical properties of these states.

One property of interest is the distribution of the spacing between adjacent levels, about which we have learned quite a bit during the last two years. The experimental facts, as obtained in the resonance scattering of slow neutrons, seem to point to the following general rules (Fig. 11).

1. The spacing between adjacent levels having the same spin and parity is distributed (relative to the mean spacing) according to a frequency function which is given to a good approximation by the Wigner distribution

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* University of Minnesota.

¹ N. Rosenzweig and C. E. Porter, Bull. Am. Phys. Soc., Ser. II, 4, 353 (1959).

$$\rho(x) = \frac{\pi}{2} x e^{-\frac{\pi}{4} x^2},$$

where $x = \text{spacing}/\text{mean spacing}$. The most characteristic feature of this distribution is that the probability of a zero spacing vanishes, i.e., neighboring levels "repel" each other. This should be compared with what one gets on the basis of the naive and incorrect supposition that the levels occur in a completely random way. The latter assumption leads to an exponential, which has its greatest value at $x = 0$.

2. The second part of the rule states that levels of different spin or parity are not in any way correlated with each other.

This has the consequence that for a set of levels which is a superposition of different spin systems, the resulting spacing distribution has a character which is intermediate between the Wigner distribution and the exponential distribution. For example, the broken line in Fig. 12 gives the calculated result for the random superposition of two spin systems which have the same mean spacing. The distribution is finite at the origin and has a peak which is less

Fig. 11. Theoretical distribution of spacings. The dashed curve represents the result of superposing two spin systems having the same mean spacing.

Fig. 12. Distribution of spacings for the odd atomic levels of Os I from 37 000 to 55 000 cm^{-1} .

pronounced than that of the Wigner distribution. In the limit of superposing, at random, a large number of different spin systems, neighboring levels evidently tend to become completely uncorrelated and the exponential distribution will be approached.

The preceding remarks were in the nature of an introduction. We now come to that

which is new.

We have found that the same statistical rules, which were first discussed in nuclear physics, hold for the spectra of many complex atoms. (Incidentally, the relevant experimental material in the atomic domain is about 100 times as abundant as that available in nuclear physics, and some of it is many years old.)

One expects that the above phenomenon is characteristic of the "complex" spectra arising from the interaction of many electrons. On the other hand, the only spectra which are useful for exhibiting the repulsion phenomenon are those in which relatively few levels have been missed by the atomic spectroscopists. It seems that both requirements are fulfilled in the regions of the periodic table in which the outermost s and d orbits compete energetically in the formation of the ground state and the low-lying excited states. This results in the particularly rich—and in many cases thoroughly analyzed—structure of odd-parity levels which arise mainly from the overlapping configurations $d^n p$ and $d^{n-1} s p$.

In Fig. 12 we give, as a typical example, the distribution of the spacing, in the form of a histogram, for the odd levels of neutral osmium. It should be clearly understood that the distribution of spacing was obtained separately for each set of levels having the same J. The

results were then combined merely to reduce the statistical fluctuations. The repulsion phenomenon is quite evident.

When the levels of osmium are not separated according to J values, the repulsion of levels should largely disappear. This is shown in Fig. 13.

The elements of the iron group give us an opportunity to see the same phenomenon when the Hamiltonian is virtually independent of the spin. In this region of the periodic table, Russel-Saunders coupling holds to a fairly good approximation. We may therefore infer what the positions of the energy levels would be in the absence of spin-orbit coupling, by computing the "center of gravity" of each multiplet. In that case parity, S, and L are constants of the motion.

Fig. 13. Distribution of spacings for the odd-parity levels of Os I. The exponential distribution is approached when the levels are not separated according to J values.

As a typical example we show the distribution between the centers of gravity of the odd multiplets of neutral iron (Fig. 14). We see that the levels having the same S and L values do indeed repel each other. Again the repulsion is greatly reduced if the levels are not separated according to symmetry character, as is shown in Fig. 15.

The above results are fairly typical of some twenty

Fig. 14. Distribution of spacings for the odd triplets and quintets of FeI (41 spacings).

Fig. 15. Distribution of spacings for the odd terms of FeI. The exponential distribution is approached when the levels are not separated according to S and L values.

Fig. 16. Distribution of spacings based on spectra for several elements. FeI odd triplets and quintets, (30 spacings); FeII odd doublets and quartets (21 spacings); TiI odd singlets and triplets (50 spacings); OsI odd levels with $J = 1, 2, 3, 4, 5, 6$ (145 spacings).

atomic spectra which we have examined to date. It is natural to suppose (and supporting theoretical arguments can be given) that the distribution of spacing observed for each element reflects the same underlying distribution. We have therefore combined (Fig. 16) the results for several atomic spectra in order to see the underlying distribution with improved statistical accuracy.

These empirical results, together with those obtained in nuclear physics, certainly support the idea that neighboring levels of the same symmetry character repel each other according to a definite statistical law (which is given to a good approximation by the Wigner distribution), and that the phenomenon is a general property of all sufficiently complex quantum systems.

18-4   Elementary Particles in DeSitter Space (formerly "Parametric Formulation of Quantum Mechanics")   (5220)

William C. Davidon

In the initial work which had been done on this project, the underlying symmetry ascribed to space-time was that of the usual Lorentz group, and the additional coordinate introduced was interpreted solely as a parameter to facilitate the relativistic description. However, it is also possible to modify the basic symmetry assumptions, in which case the additional coordinate is no longer purely a parameter, but plays a more essential role.

There are several reasons for considering such a modification of space-time symmetries. One is that the determination of the actual symmetry group of space-time can not be made a priori, but must be chosen to best describe reality. For this reason, one can not conclude that actual space-time exactly possesses the symmetry of the Lorentz group, but only that this assumption has been well confirmed. Small modifications of this assumption can still be made, however, without contradicting experience. Though these modifications are small, they may still have certain qualitative consequences. As an example, the existence of antiparticles, and the connection between spin and statistics are usually derived from the Lorentz group independently of the numerical value for the velocity of light. Hence when we consider modifications of the Lorentz group, the possibility that some implications will be of significance can not be excluded on the basis of the "smallness" of the modification.

A second reason for considering a modification to the Lorentz group is to obtain a natural way of introducing a fundamental length which is basic to all physical theories, as the Lorentz group introduces a fundamental velocity. The fundamental length so introduced is a very large one instead of

the more usual length of nuclear dimensions used as a cut-off in field theoretical calculations. With a fundamental length and velocity determined by the symmetry group, and with Planck's constant connecting the generators of the symmetry group with observables, all dimensions are determined.

There is a third motivation for these considerations of a more methodological character. That is to distinguish the consequences of symmetry assumptions more unambiguously. In order to assess the effects of any one factor in a given situation, it is valuable to consider variations in that factor while everything else is held constant, even if these variations are only considered to be virtual. Here, by considering the effects of modifications in a symmetry group differing slightly from the Lorentz group, a more thorough understanding of the Lorentz group itself is obtained.

The nature of the modification being examined is to replace the Lorentz group by the DeSitter group, which consists of all length-preserving mappings in a space-time of constant curvature. The Lorentz group is a limiting case of the DeSitter group as the curvature goes to zero, just as the Galilei group is a limiting case of the Lorentz group as the velocity of light becomes infinite. For nonvanishing curvature, the homogenous Lorentz transformations remain a subgroup of the full symmetry group, but the commutation relations among the generators of translations no longer vanish. This effect can be visualized by considering the length-preserving mappings of objects on the surface of a sphere. In order to displace the objects in the neighborhood of one point on the sphere while keeping all distances unchanged, it is necessary to rotate all the objects about an axis one quadrant away from the point in question. The possible motions as viewed in the neighborhood of any point consist of two perpendicular translations and one rotation; but, as

V-41-2

viewed on the sphere as a whole, these are three rotations. In this case, the commutator between the two translations is equal to the rotation operator divided by the square of the radius of curvature, and this relationship generalizes readily to the commutator for displacements in a curved space-time of constant curvature.

At the present time, effort is being focused on the full physical interpretation of the representation of this group. In particular, the definition of local quantities and the significance of charge are being developed.

41-2

Solvable Field Theories

(5230)

H. Ekstein

A paper entitled "Equivalent Hamiltonians in Scattering Theory" has been prepared for publication. This paper is a contribution to discussion of the question: to what extent does the scattering matrix determine the Hamiltonian? The Hamiltonians considered are nonrelativistic, but in extension of previous studies, "non-local" potentials and many-body potentials are allowed. A large class of unitary transformations is found which produce Hamiltonians leading to the same S-matrix. In the last section, it is shown that this equivalence is only a special consequence of the general axiomatic formulation of scattering in field theory.

In the course of thinking about solvable field theories, it occurred to me that, instead of formulating the problem in terms of the usual "basic fields" which have no clear physical significance, one should rather start with the physical particle-creation operators. This, however, requires a reformulation of the axioms of field theory. The present paper

contains this reformulation in Sec. IV. The first three sections are applications of the proposed axioms to an old problem, and may be considered as accidental by-products.

45-13

Meson-Nucleon Interaction

(5230)

K. Tanaka

In a previous report¹ the proton-neutron mass difference was examined by a method which introduces a complete set of intermediate states. This method of evaluating the proton-neutron mass difference has been extended to the calculation of part of the contribution to the self-mass of mesons. The effect of nucleon-antinucleon pairs around the meson (π and K) has been taken into account by introducing a form factor for the charge distribution of the meson. This form factor, which enters in a natural way, is characterized by a rms radius.

When one assumes a Yukawa model for the meson form factor, one can explain the mass difference between charged and neutral K -mesons if the charge distribution has a rms radius of $a_K = 0.48 \times 10^{-13}$ cm, a reasonable value. With the same Yukawa model, one can obtain the correct sign but not the correct magnitude of the mass difference between charged and neutral π -mesons.

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¹ ANL Physics Division Summary Report, ANL-5955 (December 1958—January 1959), p. 45.

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$^3\text{He}-^3\text{H}$ - STRAHLUNGSALTER EINES STEINMETEORITEN

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POLARIZATION MEASUREMENTS ON NUCLEAR GAMMA RAYS

Lawrence W. Fagg (Naval Research Lab.) and Stanley S.
Hanna.....
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Carl T. Hibdon.....(Project I-98)
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F. J. Lynch and R. E. Holland.....(Project I-14)
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B. James Raz.....(Project V-5)
Phys. Rev. 114, 1116-1123 (May 15, 1959).

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Sol Wexler.....(Project II-38)
J. Inorg. Nucl. Chem. 10, 8-16 (April 1959).

ELASTIC SCATTERING OF 21.6-MEV DEUTERONS BY SEPARATED ISOTOPES OF NICKEL AND COPPER

J. L. Yntema.....(Project I-22)
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J. L. Yntema and B. Zeidman.....(Project I-22)
Phys. Rev. 114, 815-820 (May 1, 1959).

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ABSTRACTS

STATISTICAL PROPERTIES OF ATOMIC SPECTRA

N. Rosenzweig and C. E. Porter (U. of Minnesota)..(Project V-15)
Bull. Am. Phys. Soc., Ser. II, 4, 353 (Aug. 27, 1959).

ADDITIONAL PAPERS ACCEPTED FOR PUBLICATION

THE DECAY OF $_{50}\text{Sn}^{113}$ (112 d) AND $_{49}\text{In}^{113\text{m}}$ (1.73 hr)

S. B. Burson, H. A. Grench, and L. C. Schmid....(Project I-37)
Phys. Rev.

THE μ MESON AND THE CATALYSIS OF NUCLEAR REACTIONS

N. D'Angelo.....
Am. J. Phys.

WAVE OPERATORS IN MULTICHANNEL SCATTERING

Melvin N. Hack.....(Project V-27)
Nuovo Cimento

A NOMOGRAPH FOR TIME-OF-FLIGHT MEASUREMENTS OF FAST NEUTRONS

R. E. Holland.....(Project I-14)
Rev. Sci. Instr.

NUCLEAR RESONANCE ABSORPTION OF GAMMA RAYS AT LOW TEMPERATURES

L. L. Lee, Jr., L. Meyer-Schützmeister, J. P. Schiffer,
and D. Vincent.....(Project I-19)
Phys. Rev. Letters.

ANALYSIS OF ANGULAR DISTRIBUTIONS IN THE REACTION $\text{B}^{11}(\alpha, \text{p})\text{C}^{14}$

L. L. Lee, Jr., and J. P. Schiffer.....(Project I-25)
Phys. Rev.

SINGLE-PARTICLE STATES OF THE NEUTRON FROM GROSS STRUCTURE IN THE PROTON SPECTRA OF (d,p) REACTIONS

J. P. Schiffer, L. L. Lee, Jr., and B. Zeidman.... (Project I-29)
Phys. Rev.

THE DECAY OF ${}_{60}\text{Nd}^{151}$ (12 min)

L. C. Schmid and S. B. Burson.....(Project I-34)
Phys. Rev.

THE DECAY OF ${}_{62}\text{Sm}^{155}$ (23.5 min)

L. C. Schmid and S. B. Burson.....(Project I-38)
Phys. Rev.

THE DECAY OF ${}_{64}\text{Gd}^{161}$ (3.73 min)

L. C. Schmid, S. B. Burson, and J. M. Cork (U. of
Michigan).....(Project I-36)

PROTON-NEUTRON MASS DIFFERENCE

Sigenobu Sunakawa and Katsumi Tanaka.....(Project V-45)
Phys. Rev.

A NEW METHOD FOR GRAPHICAL REPRODUCTION OF CATHODE-
RAY OSCILLOGRAMS

Robert K. Swank and Eugene A. Mroz.....(Project I-144)
Rev. Sci. Instr.

PERSONNEL CHANGES IN THE ANL PHYSICS DIVISION

NEW MEMBERS OF THE DIVISION

Resident Research Associates

Dr. J. P. Elliott, University of Southampton, England. Problems in the theory of nuclear structure. (Host: D. R. Inglis.)

Dr. C. S. Littlejohn. Nuclear resonance fluorescence in solids at low temperatures; polarization of protons in (d,p) reactions. (Host: J. P. Schiffer.)

Consultants

Dr. Steven A Moszkowski, University of the City of Los Angeles. Nuclear many-body problem. (Host: D. R. Inglis.)

Dr. Ben Mottelson, Institute for Theoretical Physics, Copenhagen, Denmark. Theory of nuclear structure. (Host: D. R. Inglis.)

Resident Student Associate

Mr. Huzihiro Araki, graduate student, Princeton University. Working with H. Ekstein in field theory. Came to Argonne on July 16, 1959.

Student Aide (Summer)

Mr. Neal Cason, Ripon College. Working with D. C. Hess on improvements in mass spectrometer MA-16A.

Technicians

Mr. Charles Perko, Jr. Joined the Physics Division as a research technician with S. Wexler on June 22, 1959.

Mr. John J. Vronich. Joined the Physics Division as a research technician with L. M. Bollinger on July 7, 1959.

Secretary

Mrs. Lorraine M. Beres. Joined the Physics Division on August 10, 1959 as secretary in the theoretical physics wing.

DEPARTURES

Dr. Nicola D'Angelo joined the Physics Division as a Resident Research Associate on October 19, 1956. He has collaborated with C. M. Huddleston on the measurement of the half-life of the neutron by use of a diffusion cloud chamber (Project I-117) and, more recently, with L. M. Bollinger on the half-lives of excited states of Mn^{56} (Project I-9). He terminated at ANL on August 10, 1959 to go to Princeton University, Princeton, New Jersey.

Dr. Lee J. Kieffer joined the Physics Division as a Resident Research Associate on November 11, 1957. He has collaborated with L. S. Goodman on measurements of nuclear spins and moments (Project I-80). He terminated at ANL on July 9, 1959 to go to Aeroneutronic Systems, Inc., Box 697, Newport Beach, California.

Leaves of Absence

Dr. H. Ekstein left ANL on August 27, 1959 for a year's leave of absence.

He will spend most of the year with Dr. Abdus Salam at the Mathematics Department, Imperial College, Exhibition Road, South Kensington, London, S. W. 1 but will spend one month with R. Haag in Marseilles and another month with L. van Hove in Utrecht. He plans to continue study on solvable problems in field theory and to begin work in high-energy physics and dispersion relations. He expects to return to Argonne on September 1, 1960.

Dr. Alexander Langsdorf, Jr. left ANL on June 26, 1959 for a year's leave of absence for research at the Atomic Energy Research Establishment, Harwell, Berks, England. He plans to do neutron cross-section work with their linear accelerator. He expects to return to Argonne in June 1960.

Dr. Linwood L. Lee, Jr. left ANL on August 25, 1959 for a year's leave of absence as Visiting Assistant Professor at the University of Minnesota, Minneapolis, Minnesota. He expects to return to Argonne in the summer of 1960.

Dr. John P. Schiffer left ANL on July 31, 1959 for a year's leave of absence on a Guggenheim Fellowship. He plans to work with Dr. E. Paul of the Atomic Energy Research Establishment, Harwell, Berks, England and with Dr. W. K. Jentschke of the Physikalisches Staatsinstitut, Hamburg, West Germany. He will study the average properties of nuclear levels and nuclear reactions by use of the new tandem Van de Graaff accelerator at Harwell and the Van de Graaff at Hamburg. He plans to return to Argonne in August, 1960.