

this point.¹⁰ It also suggests that a crystal of NaCl grown carefully from aqueous solution may have mechanical properties that differ in a marked way from those of a crystal grown from the melt. In this connection it is worth noting that the silver halides, and presumably the thallose halides, have about 100 times as many imperfections as do the alkali halides at the melting point. It would be interesting to know whether crystals of the silver and thallose halides grown from the melt exhibit those properties associated with dislocations more markedly than does an alkali halide crystal prepared under almost identical conditions. It is possible that a high density of such vacancies in the thallose salts promotes the prismatic slip observed by Smakula and Klein.⁹

It is highly unlikely that vacancies are trapped in a non-equilibrium manner during slow growth from the melt. Kelting and Witt¹ have found that Ca, Sr and Ba achieve equilibrium between solid and melt when crystals are grown at the rate of 1.6×10^{-5} cm/sec. We should expect vacancies to achieve equilibrium with the melt at least as easily.

¹ C. Wagner and P. Hantelmann, *J. Chem. Phys.* **18**, 72 (1950); H. Kelting and H. Witt, *Zeits. f. Physik* **126**, 697 (1949); H. Etzel and R. J. Maurer (to be published).

² E. Koch and C. Wagner, *Zeits. f. Physik* **B38**, 295 (1938); F. Seitz, *Phys. Rev.* **56**, 1063 (1939); A. W. Lawson, *Phys. Rev.* **78**, 185 (1950); J. W. Mitchell, *Phil. Mag.* **40**, 249, 667 (1949).

³ H. B. Huntington, *Phys. Rev.* **61**, 315 (1942).

⁴ R. D. Heidenreich and W. Shockley, *Report of Bristol Conference on Strength of Solids* (Phys. Soc. London, 1947), p. 57.

⁵ F. C. Frank, *Crystal Growth* (Discussions of Faraday Society, 1949), p. 48. See also paper by Frank in *Pittsburgh Symposium on Plastic Deformation of Crystalline Solids* (to be published by Naval Research Laboratory). Frank has pointed out that dislocations could be formed by precipitation of vacancies, but has not attempted to develop the idea as a practical topic. See, also, F. R. N. Nabarro, *Bristol Conference* (Phys. Soc. London, 1947), p. 75.

⁶ L. J. Griffin, *Phil. Mag.* **41**, 196 (1950).

⁷ See, for example, a paper by the writer in the *Pittsburgh Symposium* (footnote 5) and a paper by W. T. Read and W. Shockley *Imperfections in Almost Perfect Crystals* (to be published) in which these ideas are developed independently).

⁸ F. C. Frank and W. T. Read, *Phys. Rev.* **79**, 722 (1950).

⁹ A. Smakula and M. W. Klein, *J. Opt. Soc. Am.* **39**, 445 (1949); F. Seitz, *Phys. Rev.* **79**, 723 (1950).

¹⁰ R. W. James, *Optical Principles of the Diffraction of X-rays* (Bell and Sons, Ltd., London, 1949), Chapter VI. It is to be noted that M. Renninger (*Zeits. f. Krist.* **89**, 344 (1934)) has observed regions that are very nearly perfect in sodium chloride grown from the melt; however, the specimens were imperfect as a whole.

The Fierz and Kopfermann-Brix Explanation of the Spectroscopic Odd-Even Isotope Shift Staggering

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July 3, 1950

THE writer has published a note on "The Schmidt Model and the Odd-Even Staggering of the Isotopic Shift."¹ It has since been pointed out to him that very similar and in some respects identical considerations have been published previously by Fierz² and independently by Kopfermann.³ It is desired to record the fact that the credit of prior publication of the possibility of such a connection belongs to Fierz and Kopfermann. At the time of writing the note the writer was not aware of the existence of the statements by Fierz and by Brix and Kopfermann.

It may be remarked that the connection of odd-even staggering with the Schmidt model, which has been speculatively considered for some time, has become more concrete by 1950, both because of the indication of strong spin-orbit forces⁴ and the existence of calculations⁵ indicating that while the polarization of nuclei by electrons may be an appreciable contributor to the odd-even staggering there is nevertheless room for the existence of contributions from other causes.

* Assisted by the joint program of the ONR and AEC.

¹ G. Breit, *Phys. Rev.* **78**, 470 (1950).

² M. Fierz, *Göttingen Nach.* **3**, 1 (1947). This paper contains an account of a lecture to the Physical Society of Zürich, February 17, 1947.

³ P. Brix and H. Kopfermann, *Göttingen Nach.*, Heft 2, 31 (1947).

⁴ M. G. Mayer, *Phys. Rev.* **74**, 235 (1948), **75**, 1969 (1949).

⁵ Breit, Arfken, and Clendenin, *Phys. Rev.* **78**, 390 (1950).

Disintegration of Ru¹⁰³

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THE 42-day activity in Ru has been assigned^{1,2} to Ru¹⁰³. Absorption and coincidence measurements were made by Bohr *et al.*³ and Mandeville *et al.*⁴ Spectroscopic measurements were made by Hole.⁵ In the present investigation metallic Ru was bombarded in the Harwell pile⁶ and was chemically purified by W. Forsling. The pure and fine metallic powder was spread with a thickness of 4 mg/cm² over a 0.15 mg/cm² aluminum foil. Three different samples have been followed for three half-lives each, giving the half-life of Ru¹⁰³ as 39.8 ± 0.4 days.

Ru¹⁰³ has been studied in two spectrographs^{7,8} several times. One of these runs is produced in Fig. 1. The electron peaks at 17

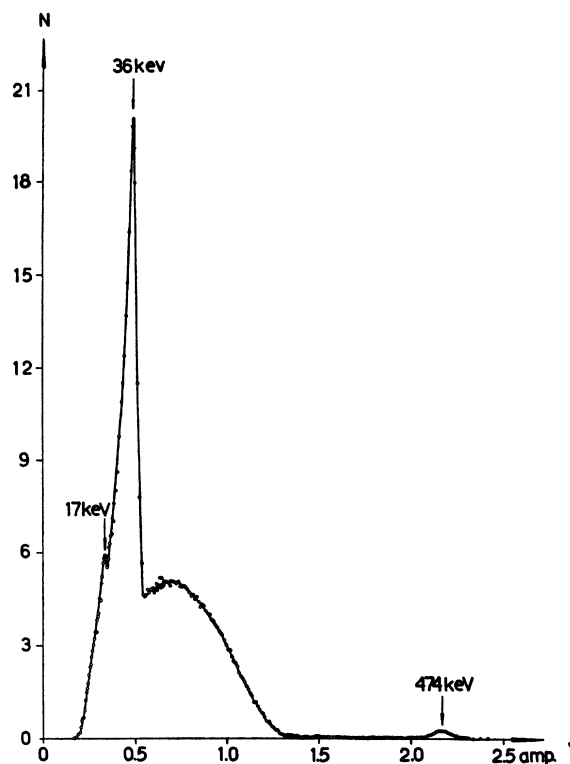


FIG. 1. Beta-ray spectrum of Ru¹⁰³.

and 36 keV are the *K* and *L* lines of 40-keV γ -ray and that at 474 keV is the *K* line of 497-keV γ -ray. The existence of the faint *K* line of 40-keV γ -ray emitted by the metastable level in Rh¹⁰³, which has not been observed before, now makes it certain that the strong β -line is an *L*-line and not a *K*-line, as has been suggested by some investigators.⁹ The photo-spectrum has also been studied in the same spectrographs, which showed two photo-lines identified as the *K* and *L* lines of a 498-keV γ -ray. From the internal conversion lines and photo-lines, the energies of the two γ -rays emitted by Ru¹⁰³ are fixed as 40.0 ± 0.5 keV and 498 ± 2 keV.

The Fermi plot of the β -spectrum shows that it is complex. The maximum energy of the hard component is found to be 698 ± 10 keV. The soft component has a maximum energy of 217 ± 4 keV. The Fermi plots of the two components seem to deviate from straight lines.

No γ - γ coincidences could be found. The β - γ coincidence rate as a function of the thickness of aluminum absorbers placed before the β -tube showed that the 498-keV γ -ray follows the soft β and not the harder one. β , e^- coincidences made in the spectrograph⁸

showed that the 36-keV conversion electrons, i.e. the 40-keV γ -ray, are not in coincidence with either of the two β -components. This shows that the 40-keV γ -ray is emitted by a metastable level.

From the β -spectrum, the K to $(L+M)$ conversion ratio for the 40-keV γ -ray is found to be 0.20 ± 0.04 . Comparison of this value with theoretical values is postponed as the present formulas do not predict exact values for such a low energy γ -ray. In the case of the 498-keV γ -ray (N_K/N_β) is found to be about one percent. Comparing this rough value with Rose's tables¹⁰ it is found that it is consistent with a 2^2 or perhaps 2^3 pole electric or magnetic transition.

A decay scheme, taking the observed facts into consideration, is suggested in Fig. 2. A discussion of the spin and parity assign-

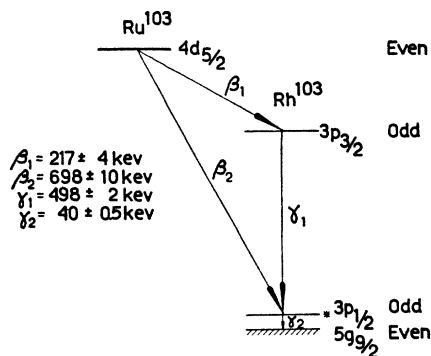


FIG. 2. Proposed decay scheme of Ru^{103} .

ments of the levels as well as the shape of the Fermi plots will be given in a detailed paper, to appear in *Arkiv för Fysik*. As an infinitely thin source can be obtained using an isotope separator, such a separation is being planned so that a more reliable value for (N_K/N_L) in the case of the 40-keV γ -ray can be given. The term scheme suggested in Fig. 2 is based on the nuclear shell theories given by Mayer¹¹ and Feenberg.¹²

I wish to convey my sincere thanks to Professor Manne Siegbahn, the director of this institute. My thanks are also due Dr. Kai Siegbahn, for constant encouragement and supervision, and Fil. Mag. W. Forsling for making the chemical purifications.

- ¹ J. J. Livingood, *Phys. Rev.* **50**, 425 (1936).
- ² Sullivan, Sleight, and Gladrow, *Phys. Rev.* **70**, 778 (1946).
- ³ E. Bohr and N. Hole, *Arkiv Mat. Astron. Fysik* **32A**, No. 15 (1945).
- ⁴ C. E. Mandeville and E. Shapiro, *Phys. Rev.* **77**, 439 (1950).
- ⁵ N. Hole, *Arkiv Mat. Astron. Fysik* **36A**, No. 2 (1948).
- ⁶ My thanks are due to Dr. Seligman for this irradiation.
- ⁷ K. Siegbahn, *Phil. Mag.* **37**, 162 (1946).
- ⁸ H. Slätis and K. Siegbahn, *Arkiv f. Fysik* **1**, No. 17 (1949).
- ⁹ H. F. Gunlock and M. L. Pool, *Phys. Rev.* **74**, 1264 (1948).
- ¹⁰ Rose, Goerzel, Spinard, Harr, and Strong, private communication; *Phys. Rev.* **76**, 184 (1949).
- ¹¹ M. G. Mayer, *Phys. Rev.* **78**, 16 (1950).
- ¹² E. Feenberg and K. C. Hammack, *Phys. Rev.* **75**, 1877 (1949).

Temperature Variation of the Compressibility of Molten Sodium

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A MODIFICATION of the standard pulse method for the measurement of sound velocity¹ permits the measurement of the temperature coefficient of this quantity for molten sodium with an accuracy better than one percent. Pulses of 12.2 Mc longitudinal waves of 1 μ sec. duration are initiated by a quartz crystal at one end of a fused quartz bar 30 cm long. A coaxial fused quartz reflecting disk is attached by quartz rods 5 cm distant from the other end of the bar, and the two are immersed in sodium melted in a vacuum furnace. Pulses reflected from the

TABLE I. Adiabatic compressibility of molten sodium.

T°C	$\mu \times 10^{12}$ cm ² /dyne
97.6	16.69
100	16.71
120	16.95
140	17.19
160	17.43
180	17.68
200	17.93
220	18.19
240	18.45
260	18.71
272	18.87

end of the bar and from the reflector are observed on a Dumont type 256D oscilloscope. An electrical time delay between the initiation of the pulse and of the oscilloscope sweep eliminates the transit time in the quartz bar and permits the use of the expanded scale of the oscilloscope, thereby enhancing the accuracy of measurement of the sound velocity.

The modification consists in the superposition, on the oscilloscope screen, of pulses received from the specimen upon others initiated simultaneously and transmitted in a carefully thermostated column of mercury the length of which is varied by means of a fine micrometer screw. Proper adjustment of this length annihilates the resultant pulse, and observation of the change in length required to maintain this condition affords the aforementioned accurate measure of the change in the sound velocity in the specimen.

Measurements made on singly and triply distilled sodium are indistinguishable. The velocity of sound at the melting point (97.6°C) is found to be $252,600 \pm 500$ cm/sec., and the temperature coefficient between this and 272°C, which is constant, to be -52.4 ± 0.3 cm/sec.-deg. Values of the adiabatic compressibility, μ , of the material computed with these data and those of Rinck² on the density of molten sodium are given in Table I.

A complete report of these experiments will be submitted for publication later.

- ¹ H. B. Huntington, *Phys. Rev.* **72**, 321 (1947).
- ² E. Rinck, *Ann. Chim. Phys.* **18**, 395 (1932).

Scattering of Positrons and Electrons by Nuclei*

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ACCORDING to relativistic quantum mechanics^{1,2} there is a marked difference between the nuclear scattering of positrons and of electrons because of the manner in which spin-orbit coupling enters into the calculation. A comparison of the scattering of electrons and positrons by light and heavy nuclei is thus a check on relativistic quantum mechanics and on the spin of the positron. For small atomic number both classical and quantum-mechanical theories agree in predicting a scattering cross section which is practically independent of sign, but for $Z/137 \approx 1$ the calculations of various authors^{2,3} show that at 57.6° a platinum foil should scatter electrons of 1.52 Mev kinetic energy nearly three times as strongly as positrons. Experimental work^{4,5} thus far tends to confirm these predictions but suffers from rather large statistical errors.

An accurate experiment to check these calculations has been carried out using electrons from 300 mc of Ce^{144} and positrons from 30.0 mc of Ga^{66} . Scattering foils were 0.015 in. of polystyrene, 0.00068 in. of copper and 0.0001 in. of platinum. Source and scatterer were placed inside a solenoidal type β -spectrograph at the conjugate foci for 0.7–1.3-Mev particles. Particles scattered down the axis of the solenoid were analyzed by a second magnetic field before detection by a thin window G-M counter in order to select only the elastically scattered particles. These particles,