tions were made to this value to take account of the following effects: 1) depolarization in the source ($0.6 \pm 1.2\%$); 2) scattering of electrons from the diaphragms, 0.5%; 3) scattering of electrons from the backing on which the gold was deposited, 0.6%; 4) arrival at the counters of electrons multiply scattered in the chamber in which the gold scatterers were placed, ($3 \pm 1.5\%$); 5) the finite range of angles and energies of the electrons which were recorded, 0.3%; 6) a coefficient for the apparatus asymmetry, 1.00 ± 0.02.

The total of all these corrections to the experimental value of the polarization does not exceed 5%. Introducing these corrections gives a value of the polarization for Sm^{153} equal to $0.90 \pm 4\%$.

The absolute values for the degree of polarization of the other nuclei which were investigated were found from the relative measurements, and are shown in the lower line of the table.

From the table we see that we succeeded in making the relative measurements to sufficiently high accuracy. It should be noted that the accuracy achieved by us in the absolute measurements is clearly insufficient. It is probable that we can improve it significantly in the near future. We also propose to make an absolute calibration of the apparatus using a beam of accelerated electrons, polarized by single scattering on gold.

[1] Ya. A. Smorodinskiĭ, Usp. Fiz. Nauk **67**, 43 (1959), Soviet Phys.–Uspekhi **2**, 1 (1959).

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POSSIBILITY OF INVESTIGATING THE LEVELS OF THE COMPOUND NUCLEUS PRODUCED BY INTERACTION BETWEEN SLOW NEUTRONS AND ISOMERS

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AN investigation of the interaction between slow neutrons with energy $E < 1$ kev and unexcited heavy nuclei disclosed the resonant structure of the cross section and yielded the parameters of the levels of the compound nucleus. There are no similar data in the 10 or 100 kev range, since the experimentally-measured cross sections are averaged over many resonances, owing to the insufficient resolving power of the apparatus as well as to the Doppler broadening.

To obtain information on the levels of the compound nucleus at high excitation energies, use can be made of the interaction between neutrons and isomers. If a nucleus in an excited isomer state is bombarded with slow neutrons, a group of levels will be excited tens or hundreds of kev above the levels of the compound nucleus that results when the unexcited target nucleus is bombarded with slow neutrons. Such an experiment would help explain how the widths and densities of levels change in a nucleus of given Z and A when the excitation energy is shifted by several tens or hundreds of kev. The spins of the two level groups should be different, since the spins of the isomer and ground states differ by several units.

It is easy to estimate very roughly the number of isomer nuclei, necessary for such an experiment, in the following manner. Let a beam of monoenergetic neutrons pass through a target of area $S \sim 1$ cm^2. Then the necessary number of isomer nuclei is $N \sim S/\sigma$, where σ is the cross section in the neighborhoods of resonance. Assume $\sigma \sim 10^3$ barns. Then the necessary number of nuclei amounts to 10^{21} or several tenths of a gram. The isomers can be accumulated by activation in a nuclear reactor, separated from fission fragments, or produced in accelerators. In a modern reactor with a neutron flux $\Phi \sim 10^{14}$ at an activation cross section $\sigma_a \sim 1$ barn, it is possible to accumulate within several months $\sigma_a \Phi t$ long-lived isomer nuclei, or 10^{-3} times the number of the nuclei in the original isotope. The fractions of several isomers in fission fragments are of the same order. Thus, an accumulation of enough isomer nuclei for the experiment is quite feasible.

The spin of the compound nucleus can be determined for many isomer nuclei.

In interactions between slow neutrons and isomers it is possible to have, along with elastic scattering (n, n) and radiation capture (n, γ), also inelastic scattering with emission of a fast neutron (n, n'), when the emitted neutron carries away the excitation energy of the isomer. When the isomer is bombarded by thermal or epithermal neutrons, the resultant fast neutrons should be highly monoenergetic. For isomers with excitation energy on the order of 100 kev, owing to the small density of the initial states and the high density of the final states, the cross section for such a reaction of inelastic "acceleration" in the region up to 100 ev is $10^3 - 10^6$ times greater than the cross section of the inverse reaction — the excitation of the isomer state by a fast neutron.

Naturally, one must expect the cross section to obey the $1/v$ law at small energies, if there is no resonant level in the vicinity.

For a rough estimate of the ratio of the widths of the reactions (n, n') and (n, γ) we assume[1] that for nuclei with $A > 80$ the neutron and radiation widths become equalized at ~ 1 kev. Since the escaping neutron has a large momentum l, then for nuclei with $kR < 1$ (see reference 1)

$$\Gamma_{n'} / \Gamma_\gamma \approx \sqrt{E'}\, (E' A^{2/3} \cdot 10^{-4})^l / [(2l-1)!!]^2, \qquad (1)$$

where E is the energy of the emitted neutron in kev.

Isomer	T	I_m	I	E', kev	$10^3 \frac{\Gamma_{n'}}{\Gamma_\gamma}$
$_{41}Nb^{91m}$	64 d	1/2−	9/2+	104	0.4
$_{43}Tc^{97m}$	91 d	1/2−	9/2+	99.2	0.4
$_{47}Ag^{110m}$	270 d	6−	2+	116	0.9
$_{48}Cd^{113m}$	5.11 yr	11/2−	1/2+	265	$2 \cdot 10^{-3}$
$_{52}Te^{125m}$	58 d	11/2−	3/2+	110	1

For certain long-lived isomers[2] the table lists the lifetimes T, the spins I and I_m and the parities of the final and initial states, the transition energy E′, and also the ratio $\Gamma_{n'}/\Gamma_\gamma$, estimated from formula (1). For all the isomers given, with the exception of Cd^{113m}, the (n, n') reaction is accompanied by spin flip, since $\Delta I = 4$, and the parities of the initial and final states are opposite. The table lists the values of $\Gamma_{n'}/\Gamma_\gamma$, for $l = 3$. For $l = 5$ these values are $10^4 - 10^5$ times smaller. Thus, given the intensity of the fast neutrons produced in the (n, n') reaction, we can determine the spin of the compound nucleus for these isomers.

In conclusion, I express my gratitude to V. N. Gribov, A. D. Piliya, and M. I. Pevzner for discussion of our work.

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[2] B. S. Dzhelepov and L. K. Pekar, Схемы распада радиоактивных ядер (Decay Schemes of Radioactive Nuclei), U.S.S.R. Acad. Sci., 1958.

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ON THE INCLUSION OF EXCHANGE IN THE THEORY OF COLLISIONS

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THE formulation of the problem of scattering of electrons by atoms, which has been given by Drukarev,[1] reduces in the case of the hydrogen atom to the solution of the system of integro-differential equations

$$(\Delta_1 + k_\alpha^2)\, F_\alpha^\pm (\mathbf{r}_1) = \underset{\beta}{\mathrm{S}}\, F_\beta^\pm (\mathbf{r}_1)\, 2 \int \psi_\alpha^* (\mathbf{r}_2) \left(\frac{1}{r_{12}} - \frac{1}{r_1}\right) \psi_\beta (\mathbf{r}_2)\, d\mathbf{r}_2 \pm A_\alpha^\pm (\mathbf{r}_1), \qquad (1a)$$

with boundary conditions

$$F^\pm (\mathbf{r}) \underset{r\to\infty}{\sim} \delta_{\alpha 0} \exp (i k_\alpha z) + a_\alpha^\pm (\theta, \varphi)\, r^{-1} \exp (i k_\alpha r), \qquad (1b)$$

where α and β denote the sets of quantum numbers characterizing the hydrogen atomic states, for example (nlm) or (klm); S denotes summation over the discrete and integration over the continuous spectrum; $k_\alpha^2 = 2(E - \epsilon_\alpha)$, where ϵ_α are the energy levels of the hydrogen atom;

$$A_\alpha^\pm (\mathbf{r}_1) = \underset{\beta}{\mathrm{S}}\, \psi_\beta (\mathbf{r}_1)\, 2 \int \psi_\alpha^* (\mathbf{r}_2) \left(\frac{1}{r_{12}} + \varepsilon_\beta - \frac{1}{2} k_\alpha^2\right) F_\beta^\pm (\mathbf{r}_2)\, d\mathbf{r}_2$$

$$= \int \psi_\alpha^* (\mathbf{r}_2)\, (H - E)\, \underset{\beta}{\mathrm{S}}\, \psi_\beta (\mathbf{r}_1)\, F_\beta^\pm (\mathbf{r}_2)\, d\mathbf{r}_2, \qquad (2)$$

$$H = -\tfrac{1}{2}\Delta_1 - \tfrac{1}{2}\Delta_2 - 1/r_1 - 1/r_2 + 1/r_{12}. \qquad (3)$$

For a unique solution the function $\Phi^\pm(\mathbf{r}_1, \mathbf{r}_2) = \underset{\alpha}{\mathrm{S}}\, [F_\alpha^\pm(\mathbf{r}_1)\, \psi_\alpha(\mathbf{r}_2) \pm F_\alpha^\pm(\mathbf{r}_2)\, \psi_\alpha(\mathbf{r}_1)]$ must be required to have the asymptotic form*

$$\Phi^\pm (\mathbf{r}_1, \mathbf{r}_2) \underset{r_1\to\infty}{\sim} \underset{\alpha}{\mathrm{S}}\, \psi_\alpha (\mathbf{r}_2)\, [\delta_{\alpha 0} \exp (i k_\alpha z_1) + a_\alpha'^\pm (\theta_1, \varphi_1)\, r_1^{-1} \exp (i k_\alpha r_1)]. \qquad (1c)$$

For practical calculations, we solve instead of the infinite system (1a) a reduced system consisting, for example, of one or two equations. In this case one obtains appreciable differences between a_α^+ and a_α^-.

It is not always sufficiently clearly recognized that for an accurate solution of the infinite system the relation

$$a_\alpha^+ = \alpha_\alpha^- \qquad (4)$$

must be satisfied.

To prove this it is sufficient to show that there is a solution for which $A_\alpha^\pm = 0$. But this property describes the solution which is distinguished by the