palladium-hydrogen are explained not by the feature of the chemical bond Pd–H, but, for example, by the structural changes of the crystal lattice. It is known that in palladium hydride, in contrast to the other hydrides of the transition metals, except CrH, the hydrogen fills octahedral vacancies without first filling tetrahedral vacancies.[1]

Since the capture probability of π^- mesons by hydrogen $W \approx 0$ for strong OH-acids (HNO_3, H_2SO_4) with a long ionic bond O–H, the value of W obtained by us for the hydride $PdH_{0.67}$ refutes the hypothesis that hydrogen in it, as also in other metallic hydrides, is predominantly in the form of the proton H^+. Preference should apparently be given to the idea of Gibbs[12] that H^+ is H^- in an excited state and exists in an insignificant amount in equilibrium with H^-. From this point of view, all the steric and chemical characteristics of palladium hydride are determined by the properties of the hydride ion H^-, while the high mobility—by the specific properties of the proton H^+.

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1) The sample of $TiH_{1.65}$ was prepared by A. A. Chertkov (Institute of General and Organic Chemistry, USSR Academy of Sciences).

[1] K. M. MacKay, Hydrogen Compounds of Metallic Elements, Spon, 1966 (Russ. transl. Mir, 1968, p. 126).

[2] B. Siegel and G. G. Libowitz in: Metal Hydrides, ed., W. M. Mueller, J. P. Blackledge, and G. G. Libowitz, Acad. Press, New York, 1968, p. 545.

[3] M. E. Kost, Z. V. Kumshteǐn, V. I. Mikheeva, L. N. Padurets, V. I. Petrukhin, V. M. Suvorov, A. A. Chertkov, and I. A. Yutlandov, ZhNKh 21, 1444 (1976).

[4] Z. V. Krumshteǐn, V. I. Petrukhin, L. M. Smirnova, V. M. Suvorov, and I. A. Yutlandov, Joint Inst. Nuclear Research R12-5224, Dubna, 1970).

[5] L. Vil'gel'mova, P. Zimrot, V. I. Petriukhin, V. E. Risin, L. M. Smirnova, V. M. Suvorov, and I. A. Yutlandov, Zh. Eksp. Teor. Fiz. 65, 24 (1973) [Sov. Phys. JETP 38, 12 (1974)].

[6] B. Stalinski, C. K. Coogan, and H. S. Gutowsky, J. Chem. Phys. 34, 1191 (1961).

[7] W. Spalthoff, Z. Phys. Chemie N. F. 29, 258 (1961).

[8] V. I. Petrukhin, Proceedings, IV Intern. Conf. on High Energy Physics and Nuclear Structure, Joint Inst. Nuclear Research, D1-6349, Dubna 1972.

[9] S. S. Gershteǐn, V. I. Petrukhin, L. I. Ponomarev, and Yu. D. Prokoshkin, Usp. Fiz. Nauk 97, 3 (1969) [Sov. Phys. Usp. 12, 1 (1970)].

[10] G. Bohmhodt and E. Whicke, Z. Phys. Chemie, N. F. 56, 133 (1967).

[11] F. A. Lewis, in The Palladium/Hydrogen System, Acad. Press, New York, 1967, p. 1.

[12] T. R. P. Gibbs, Prog. Inorg. Chem., 3, 315 (1962).

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Measurement of the polarization correlation coefficient C_{nn} of elastic pp scattering at energies of 550 and 630 MeV

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The polarization correlation coefficient C_{nn} was determined for the elastic pp scattering at energies of 550 and 630 MeV for four scattering angles. The coefficient C_{nn} was determined by scattering a beam of protons of 0.34–0.36 polarization by a "frozen" polarized proton target with maximum polarization of 0.98 ± 0.03. The results of the measurements indicated that, in the investigated energy range, C_{nn} depended weakly on the angle and energy.

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The energy and angular dependences of the polarization correlation coefficient C_{nn} were determined in the range 550–630 MeV by measuring C_{nn} for 550 ± 15 and 630 ± 10 MeV and four scattering angles $\vartheta = 41, 69, 77, 91^\circ$ and $\vartheta = 40.6, 69.6, 78, 92^\circ$, respectively (center-of-mass system). The experimental method and the features of the apparatus were described in detail earlier.[1] A polarized proton beam of 0.34–0.36 polarization and a polarized proton target of the "frozen" type with maximum polarization 0.98 ± 0.03 were used. The coefficient C_{nn} was determined by measuring the intensity of the scattered proton beam produced as a result of scattering of the polarized beam by the target and this was done for various combinations of the beam and target polarizations: I_{++}, I_{+-}, I_{-+}, and I_{--}, where the first index identifies the direction of polarization of the target and the second that of the beam relative to the normal of the left-hand scattering plane.

The measurements were carried out during five-minute exposures. The sign of the target polarization changed after 8–12 h operation and the sign of the beam

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TABLE I.

$T=550$ MeV		$T=630$ MeV		
ϑ, deg (center-of-mass system)	ε run I	ϑ, deg (center-of-mass system)	ε run II	ε run III
41	0.174±0.012	40.6	–	0.129±0.010
69	0.171±0.004	69.6	0.143±0.007	0.165±0.005
77	0.186±0.005	78	0.174±0.006	0.171±0.005
91	0.164±0.004	92	0.179±0.005	0.192±0.005

Note: Experimental conditions in run I:

$P_T^- = 0.89\pm0.03$, $P_B^- = 0.36\pm0.02$, $\tau = 0$, $\beta = 0$:

run II:

$P_T^- = 0.89\pm0.03$, $P_B^- = 0.322\pm0.016$, $\tau = 0.03\pm0.02$, $\beta = 0.17\pm0.05$;

run III:

$P_T^- = 0.93\pm0.03$, $P_B^- = 0.34\pm0.02$, $\tau = -0.03\pm0.02$, $\beta = 0.12\pm0.05$.

polarization after 16–24 h. The background due to complex nuclei in the polarized target (propanediol $C_2H_8O_2$) was determined for the scattering of an unpolarized proton beam by a hydrogen-free equivalent of a polarized proton target (activated charcoal). The angular resolution of the detectors was ±0.75° (laboratory system). A computer was used to control the stability of the experimental conditions and to record the results.

Measurements of the four intensities I_{++}, I_{+-}, I_{-+}, and I_{--} made it possible, in principle, to determine four independent quantities, for example, the intensity I_0 of the scattering of an unpolarized beam by an unpolarized target, C_{nn}, target polarization, and beam polarization. Thus, the problem of determination of C_{nn} could be solved by the method of least squares without data on the beam P_B and target P_T polarizations. However, in practice it was not always possible to maintain the absolute signs of the beam and target polarizations during their measurements. The number of unknowns then increased to six and additional data (for example, the polarizations P_T and P_B) were needed to determine them. In our case the target polarization P_T was determined by the NMR method and it was checked at 630 MeV by comparison with the elastic pp scattering through 20° (laboratory system). The beam polarization P_B was measured with a special polarimeter[1] which gave the asymmetry of the elastic pp scattering through 20° (laboratory system).

Four values of the intensity I determined experimentally for various directions of P_B and P_T made it possible to deduce the following asymmetries:

$$\left.\begin{aligned}\varepsilon_{+-,\,+-}&=(I_{++}-I_{+-}+I_{--}-I_{-+})\,(I_{++}+I_{+-}+I_{--}+I_{-+})^{-1},\\ \varepsilon_{+-,\,-}&=(I_{+-}-I_{--})\,(I_{+-}+I_{--})^{-1},\\ \varepsilon_{+-,\,+}&=(I_{++}-I_{-+})\,(I_{++}+I_{-+})^{-1},\\ \varepsilon_{+,\,+-}&=(I_{++}-I_{+-})\,(I_{++}+I_{+-})^{-1},\\ \varepsilon_{-,\,+-}&=(I_{--}-I_{-+})\,(I_{--}+I_{-+})^{-1}.\end{aligned}\right\}\qquad(1)$$

The identity, within the limits of the experimental error, of the values of C_{nn} deduced from different types of asymmetry (1) should be evidence of the absence of significant systematic experimental errors.

TABLE II.

$T=550$ MeV			$T=630$ MeV			
ϑ, deg (center-of-mass system)	run I		ϑ, deg (center-of-mass system)	run II	run III	
	C_{nn}	$C_{nn}^{(fit)}$		C_{nn}	C_{nn}	$C_{nn}^{(fit)}$
41	0.54±0.05	0.57	40.6	–	0.44±0.05	0.46
69	0.58±0.04	0.59	69.6	0.55±0.06	0.54±0.05	0.56
77	0.53±0.04	0.55	78	0.66±0.06	0.56±0.05	0.63
91	0.51±0.04	0.53	91	0.69±0.05	0.64±0.05	0.68

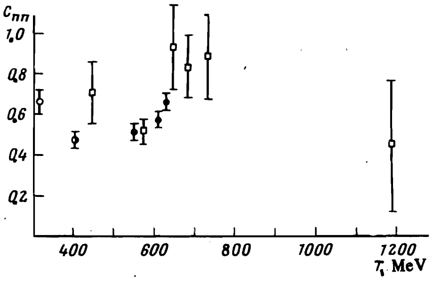

FIG. 1. Energy dependence of the polarization correlation coefficient C_{nn} of the elastic pp scattering through $\vartheta=90°$ (center-of-mass system): ○) average data for 307, 330,[5] 315,[6] 320[7] MeV; ◑) average data for 382,[8] 386 and 415,[5] 399[9] MeV; □) 449,[9] 575,[10] 650,[11] 683,[12] 745 and 1190[13] MeV; ●) 610 MeV,[1] 550 and 630 MeV—our results.

RESULTS

The asymmetries $\varepsilon_{+-,+-}$ found are listed in Table I.

Table II gives the values of C_{nn} deduced from the measured asymmetries $\varepsilon_{+-,+-}$:

$$C_{nn}=\frac{\varepsilon_{+-,\,+-}[1-0.5\,(\beta P_B+\tau P_T)\,\mathbf{P}_{pp}\cdot\mathbf{n}]}{P_BP_T[\,(1-0.5\beta)\,(1-0.5\tau)-0.25\beta\tau\varepsilon_{+-,\,+-}]},\qquad(2)$$

where $\mathbf{P}_{pp}$ is the polarization in the elastic pp scattering; $\tau=1-P_T^+/P_T^-$; $\beta=1-P_B^+/P_B^-$; $P_B=P_B^-$; $P_T=P_T^-$; $P_T^+(P_T^-)$ and $P_B^+(P_B^-)$ are the target and beam polarizations, respectively, with the positive (negative) directions relative to the normal $\mathbf{n}$ of the left-hand scattering plane.

The errors in Table II include not only the random errors but the errors in the measurement of the target polarization ($\Delta P_T/P_T=0.03$) and of the beam polarization ($\Delta P_B/P_B=0.06$). For comparison, Table II includes also the values of $C_{nn}^{(fit)}$ obtained if the asymmetries (1) are found by the least-squares method assuming that C_{nn}, τ, and β are free parameters.

The values of C_{nn} for 630 MeV were used to refine the phase analysis of the pp scattering at 630 MeV, carried out by us earlier.[2] It was found that the set of values B found earlier[2] should be rejected in accordance with the χ^2 criterion ($\chi^2/\overline{\chi^2}=1.24$ for $\overline{\chi^2}=246$, reliability level 0.006) if the phase analysis was carried out using the earlier data.[2] However, if the phase analysis included the data on the differential cross sections of the elastic pp scattering through small angles taken from the work of the groups of Vorob'ev and Zul'karneev,[3,4] the description of the experimental data deteriorated so much that both sets had to be rejected in accordance with the χ^2 criterion.

Figure 1 shows the energy dependence of the polarization correlation coefficient $C_{nn}(90°)$ for the scattering through 90° (center-of-mass system). It is clear from Fig. 1 that an increase in the energy from 550 to 630 MeV resulted in some increase of C_{nn} by an amount equivalent to 3.5 errors. Unfortunately, the high-energy data were insufficiently accurate to draw any definite

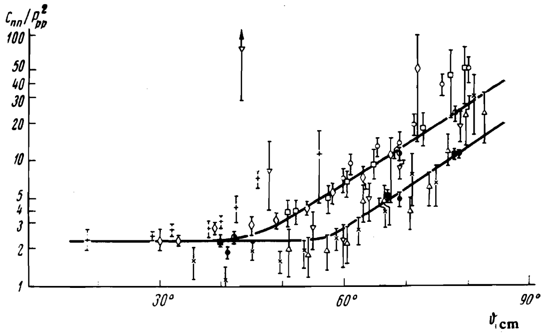

FIG. 2. Dependence of C_{nn}/P_{pp}^2 on the scattering angle ϑ (center-of-mass system): ■) 610 MeV;[1] ●) 630 MeV, ◑) 550 MeV—our results; ◻) 415 MeV;[5] ○) 307 MeV;[5] △) 683 MeV;[12] ×) 735 MeV;[13] ◇) 1271 MeV;[15] +) 2200 MeV;[15] ▽) 11470 MeV.[16]

conclusions on the energy dependence of the polarization correlation coefficient between 630 and 1000 MeV.

Durand and Halzen[14] have shown that when all the spin effects in the *pp* scattering are due to a weak spin-orbit interaction, the following relationship applies

$$C_{nn}(s,t)/P_{pp}^2(s,t)=f(t), \tag{3}$$

where *s* and *t* are the Mandel'shtam variables. Although we could hardly expect that the assumptions made by Durand and Halzen[14] to derive Eq. (3) are valid at energies of 550–630 MeV, nevertheless we used the values of C_{nn} obtained at 550, 610,[1] and 630 MeV to check this relationship. Such a check indicated that the values of the function $f(t)$ corresponding to $\vartheta = 41°$ ($t = 0.25$) confirmed satisfactorily the scaling behavior of the relation ship $C_{nn}(s,t)/P_{pp}^2(s,t)$ even beginning from the energies 550–630 MeV used in our experiments.

At higher scattering angles the values of the ratio $C_{nn}(s,t)/P_{pp}^2(s,t)$ begin to deviate considerably from those obtained by Durand and Halzen[14] for higher energies. This, however, can be explained by the fact that for $t = -MT$, where M is the proton mass and T is its kinetic energy, the polarization in the *pp* scattering vanishes ($\vartheta = 90°$), whereas the polarization correlation coefficient remains finite. The influence of this singularity of $f(t)$ can be eliminated by considering the dependence of the ratio C_{nn}/P_{pp}^2 on the scattering angle ϑ for all the currently available data on P_{pp} and C_{nn}, beginning from 300 MeV. The resultant dependence is shown in Fig. 2. It is clear from this figure that the majority of the values of the ratio C_{nn}/P_{pp}^2 deduced from the published data is clustered satisfactorily around a certain common curve with the possible exception of the 600–735 MeV range. This may be due to the energy dependence of $C_{nn}(90°)$ in the range 600–735 MeV. It seems to us that this behavior of the ratio C_{nn}/P_{pp}^2 can hardly be explained by the existence of a weak spin–orbit interaction at such low energies.

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[1] N. S. Borisov, L. N. Glonti, M. Yu. Kazarinov, Yu. M. Kazarinov, Yu. F. Kiselev, V. S. Kiselev, V. N. Matafonov, G. G. Macharashvili, B. S. Neganov, I. Strakhota, V. N. Trofimov, Yu. A. Usov, and B. A. Khachaturov, Zh. Eksp. Teor. Fiz. **72**, 405 (1977) [Sov. Phys. JETP **45**, 212 (1977)].

[2] L. N. Glonti, Yu. M. Kazarinov, V. S. Kiselev, and I. N. Silin, Preprint R1-6339, Joint Institute for Nuclear Research, Dubna, 1972.

[3] A. A. Vorob'ev (Vorobyov), A. S. Denisov, Yu. K. Zalite, G. A. Korolev, V. A. Korolev, G. G. Kovshevnyĭ (Kovshevny), E. (Ye.) M. Maev, V. I. Medvedev, G. L. Sokolov, G. E. (Ye.) Solyakin, E. M. Spiridenkov, I. I. Tkach, and V. A. Shchegelskiĭ (Schegelsky), Phys. Lett. B **41**, 639 (1972).

[4] I. V. Amirkhanov, V. I. Bystritskiĭ, L. S. Vertogradov, R. Ya. Zul'karneev, R. Kh. Kutuev, Kh. Murtazaev, V. S. Nadezhdin, and V. I. Satarov, Yad. Fiz. **17**, 1222 (1973) [Sov. J. Nucl. Phys. **17**, 636 (1973)].

[5] A. Beretvas, Phys. Rev. **171**, 1392 (1968).

[6] I. M. Vasilevskiĭ, V. V. Vishnyakov, E. Iliesku, and A. A. Tyapkin, Zh. Eksp. Teor. Fiz. **45**, 474 (1963) [Sov. Phys. JETP **18**, 327 (1964)].

[7] J. V. Allaby, A. Ashmore, A. N. Diddens, J. Eades, G. B. Huxtable, and K. Skarsvag, Proc. Phys. Soc. London **77**, 234 (1961).

[8] A. Ashmore, A. N. Diddens, G. B. Huxtable, and K. Skarsvag, Proc. Phys. Soc. London **72**, 289 (1958).

[9] E. Engels Jr., T. Bowen, J. W. Cronin, R. L. McIlwain, and L. G. Pondrom, Phys. Rev. **129**, 1858 (1963).

[10] G. Coignet, D. Cronenberger, K. Kuroda, A. Michalowicz, J. C. Oliver, M. Poulet, J. Teillac, M. Borghini, and C. Ryter, Nuovo Cimento A **43**, 708 (1966).

[11] B. M. Golovin, V. P. Dzhelepov, and R. Ya. Zul'karneev, Zh. Eksp. Teor. Fiz. **41**, 83 (1961) [Sov. Phys. JETP **14**, 63 (1962)].

[12] H. E. Dost, J. F. Arens, F. W. Betz, O. Chamberlain, M. J. Hansroul, L. E. Holloway, C. H. Schultz, and G. Shapiro, Phys. Rev. **153**, 1394 (1967).

[13] G. Cozzika, Y. Ducros, A. de Lesquen, J. Movchet, J. C. Raoul, L. van Rossum, J. Deregel, and J. M. Fontaine, Phys. Rev. **164**, 1672 (1967).

[14] L. Durand and F. Halzen, Phys. Rev. D **15**, 352 (1977).

[15] D. Miller, C. Wilson, R. Giese, D. Hill, K. Nield, P. Rynes, B. Sandler, and A. Yokosawa, Phys. Rev. Lett. **36**, 763 (1976).

[16] K. Abe, R. C. Fernow, T. A. Mulera, K. M. Terwilliger, W. De Boer, A. D. Krisch, H. E. Miettinen, J. R. O'Fallon, and L. G. Ratner, Phys. Lett. B **63**, 239 (1976).

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