the experimentally observed degree of polarization at room temperature.

The figure shows that with increasing temperature, the signal strength is reduced. The experimental signal strength ratio at 0 and 57° is 1.15, and the corresponding ratio of the values of P calculated from Eq. (1) is 1.21.

Our data are a basis for concluding that the resonance line width increases as the temperature drops.

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Translated by I. Emin
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The Character of Nucleonic Forces

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(Submitted to JETP editor November 6, 1956)
J. Exptl. Theoret. Phys (U.S.S.R.) **32**, 612-614 (March, 1957)

ANALYSIS of experimental data on proton-proton scattering apparently allows us to draw the conclusion that the principal role is played by $^1S_0$ and $^3P_0$ states in the energy region up to 400 Mev[1-3]. There is no basis for thinking that the concept of a potential is generally inapplicable in this region of energy; however, numerous attempts to explain the observed character of the scattering and polarization for pp and np collisions, using central, tensor and (lS)-forces[4], have been unsuccessful. In order to describe the large contribution of $^3P_0$ and the small contribution of $^3P_1$ and $^3P_2$ states, we introduce the interaction operator in the form

$$\hat{U} = {}^1/_4\,(1-\sigma_1\sigma_2)\,V_1 + {}^1/_3\,V_2\,[(\mathrm{lS})^2-\beta], \qquad (1)$$

where $\frac{1}{2}\sigma$ and l are the spin and orbital momentum operators of the nucleon, $\mathrm{S}=(\sigma_1+\sigma_2)/2$; V_1, V_2 and β are functions of the invariants r, $\partial/\partial r$, S^2 and l^2, while β is such a function that $\beta\psi_{^3P} = \psi_{^3P_0}$; $\psi_{^3P}$ is the wave function of the system in ^3P states. It is not difficult so to choose β that the second term in (1) plays a role only in the triplet states, for example, $\beta = l^2S^2/4$. It is obvious that

$$\hat{U}\psi_{^3P_0} = V_2\psi_{^3P_0},\quad \hat{U}\psi_{^3P_1} = \hat{U}\psi_{^3P_2} = 0,$$

i.e., $\hat{U}$ does not act on the $^3P_1$ and $^3P_2$ states.

We shall not consider here a possible explicit form for V_1 and V_2, since the existing phase analysis is not unique and does not give reliable information on the phases. Nevertheless, data on the character of the interaction in ^3P states make reasonable the separation of the forces in the form (1) and the consideration of the remaining part of the potential (which leads to scattering into the states $^3P_1$ and $^3P_2$) as a small correction. It is possible to choose the values of V_1 and V_2 to account for $\delta_{^1S_0}$ and $\delta_{^3P_0}$, and to guarantee the smallness of all the remaining phases[5,6].

A more accurate description of $^1D_2$, ^3F and the other states, and also an account of the small contribution of $^3P_1$ and $^3P_2$ can be achieved by the introduction into $\hat{U}$ of additional terms [tensor forces, (lS) forces] of corresponding magnitude. We note that a small phase shift $\delta_{^3P_1}$ and $\delta_{^3P_2}$, which does not appreciably disturb the isotropy of the angular distribution, can have a strong effect on the character of the polarization of the nucleons.

Data on np scattering at $T=0$ could be explained on the basis of the assumption of a central static potential[1]. If a detailed analysis shows that forces of the form $V_2[(\mathrm{lS})^2-\beta]$ do not give an appreciable contribution at $T=0$, then V_2 can be multiplied by $(1+\tau_1\tau_2)$, where τ is the isobaric spin operator of the nucleons.

A number of authors[7,8] have pointed out that in the nuclear shell model, along with $(\mathrm{l}\sigma)$ forces, one must introduce other, velocity-dependent forces. For example, Nilsson[8] has observed that the expression for the average potential of a nucleus ought to contain terms proportional to l^2. We note that $l^2 \equiv (\mathrm{l}\sigma)^2$, *i.e.*, it has the same character as the operator $(\mathrm{lS})^2$ in Eq. (1). It is well known that velocity-potentials are equivalent to nonlocal potentials (the potential operator is an integral operator). It is possible that the appearance of terms of the form $V_2[(\mathbf{lS})^2-\beta]$ in the interaction potential of two nucleons (for $T=1$) reflects the nonlocal character of of this interaction.

Let us consider the general case of velocity-dependent forces. The potential between two nucleons can depend on four vector operators $\mathbf{n}=\mathbf{r}/r$, $\boldsymbol{\sigma}_1, \boldsymbol{\sigma}_2$ and $\mathbf{l}$, and on the scalar operators r, $\partial/\partial r$, l^2.

Examples are given in the papers of Simon[9] and Racah[10] of irreducible tensor operators acting on spin space. In similar fashion we can introduce operator functions $Y_{N\nu}(\mathbf{l})$, whose components are transformed in a rotation of coordinates according to a $(2N+1)$ dimensional irreducible respresentation. For example,

$$Y_{00}(\mathbf{l})=1;\quad Y_{10}(\mathbf{l})=l_z;\quad Y_{1\pm1}(\mathbf{l})=\pm\sqrt{\frac{1}{2}}(l_x\pm il_y);$$

$$Y_{20}(\mathbf{l})=\sqrt{\frac{1}{6}}(3l_z^2-l^2);$$

$$Y_{2\pm1}(l)=\pm\frac{1}{2}[(l_x\pm il_y)\,l_z+l_z\,(l_x\pm il_y)];$$

$$Y_{2\pm2}(\mathbf{l})=\frac{1}{2}(l_x\pm il_y)^2.$$

$Y_{N\nu}(\mathbf{l})$ must be so constructed that its form does not change upon permutation of l_z and $l_x\pm il_y$. Only in this case will the representation be irreducible.

An explicit form for $Y_{N\nu}(\mathbf{l})$ can be found by means of the relation

$$Y_{N\nu}(\mathbf{l})=\frac{1}{2}\sum_{\nu_1,\nu_2}C^{N\nu}_{N-1\nu_1,\,1\nu_2}\{Y_{N-1\nu_1}(\mathbf{l}),\;Y_{1\nu_2}(\mathbf{l})\},\quad (2)$$

where { } represents and anti-commutator, while C...... are the Clebsh-Gordan coefficients:

$$Y_{N\nu}(\mathbf{l})\,Y_{lm}(\vartheta\varphi)=A_{Nl}C^{l\mu}_{N\nu lm}Y_{l\mu}(\vartheta\varphi).\quad (3)$$

In order to compute the A_{Nl}, it is necessary to make use of the explicit form of $Y_{N\nu}(\mathbf{l})$, where we can take any convenient values for ν and m, since the A_{Nl} do not depend on them.

Let S be the operator of the total spin of the system of particles of spin ½. We can then construct [in a fashion similar to (2)] operator functions $Y_{N\nu}(S)$. By virtue of the commutation properties of the σ_k, they can be shown to differ from zero only for $N\leqslant 2S$. For example, $Y_{N\nu}(\sigma)\neq 0$ only for $N=0$ or 1.

Since T is a sufficiently good quantum number, transitions between singlet and triplet states are improbable; this means that $\boldsymbol{\sigma}_1$ and $\boldsymbol{\sigma}_2$ ought to enter symmetrically into the potential. Therefore, we have only $\mathbf{n}$ and $\mathbf{l}$ left at our disposal. The invariant function of these operators, which can be regarded as the interaction potential, has the form

$$\hat{U}=\sum B^{Ng}_{N_1N_2}\left(r,\frac{\partial}{\partial r},\,S^2,\,l^2\right)\gamma_g C^{N\nu}_{N_1\nu_1N_2\nu_2}Y^*_{N\nu}(\vartheta\varphi)\,Y_{N_1\nu_1}$$
$$\times(\mathbf{l})\,Y_{N_2\nu_2}(S),\quad (4)$$

where $\gamma_0=1$, $\gamma_1=\tau_1\tau_2$; $B^{Ng}_{N_1N_2}$ are functions of invariant operators. The summation is taken over all possible values of N_i, ν_i and g. Only those N_i are possible which leave (4) invariant relative to inversion of the coordinate system ($\mathbf{r}\to-\mathbf{r}$) and to time reversal ($\mathbf{l}\to-\mathbf{l}$, $\boldsymbol{\sigma}\to-\boldsymbol{\sigma}$). It is easy to see that $\hat{U}$ contains all forms of potentials which are usually considered.

If account is taken of the possibility of transitions between states with different S, then we make the following substitution in Eq. (4):

$$Y_{N_2\nu_2}(S)\to\sum b^{N_2}_{N_3N_4}C^{N_2\nu_2}_{N_3\nu_3N_4\nu_4}Y_{N_3\nu_3}(\sigma)\,Y_{N_4\nu_4}(\sigma),$$

where $b^{N_2}_{N_3N_4}$ is a function of the invariant operators, symmetrized for N_3, ν_3 and N_4, ν_4. The operator $(\mathbf{lS})^2-\beta$ selects one state of all the possible states with $S=1$ and $l=1$, the state with the definite value of total angular momentum $J=0$. We give a general method for the construction of such projection operators for arbitrary l, S and J. We shall seek the projection operator in the form

$$\Pi^J_{lS}\psi^{j\mu}_{lS}=\sum_{N\nu}\alpha^N_{lS}(-1)^\nu Y_{N-\nu}(S)\,Y_{N\nu}(\mathbf{l})\,\psi^{j\mu}_{lS}=\delta_{Jj}\psi^{j\mu}_{lS},$$

where $\psi^{j\mu}_{ls}$ is the wave function with definite values of the total angular momentum j and momenta l and S:

$$\psi^{j\mu}_{lS}=\sum_{m,\sigma}C^{j\mu}_{lmS\sigma}\psi_{S\sigma}(\xi)\,Y_{lm}(\vartheta\varphi).\quad (5)$$

Making use of Eq. (3) and the orthogonality relations for the Racah functions[10] $W(abcd;ef)$, we obtain

$$\alpha^N_{lS}=(2N+1)(2J+1)(-1)^{S+l-J}A^{-1}_{NS}A^{-1}_{Nl}[(2l+1)$$
$$\times(2S+1)]^{-1/2}\,W(llSS;\,NJ).\quad (6)$$

Since

$$(\mathbf{lS})=\sum_\nu(-1)^\nu Y_{1-\nu}(\mathbf{S})\,Y_{1\nu}(\mathbf{l}),$$

then, for $S=½$, we obtain the well-known relation

$$\Pi^{J}_{l\frac{1}{2}} = [2J+1+8(J-l)(lS)]\,[2(2l+1)]^{-1}.$$

The projection operator on the state with given L, S and J of the form

$$P^{J}_{LS}\psi^{j\mu}_{ls} = \delta_{Jj}\delta_{Ll}\delta_{Ss}\psi^{J\mu}_{LS}$$

is an integral operator with kernel

$$\sum_{M}\psi^{JM}_{LS}(\xi,\vartheta,\varphi)\,\psi^{JM}_{LS}(\xi',\vartheta',\varphi').$$

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Photodisintegration of Neon Nuclei

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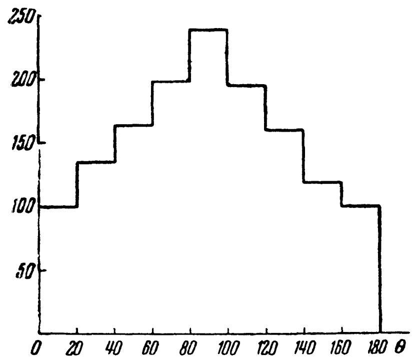
(Submitted to the JETP editor November 24, 1956)

J. Exptl. Theoret. Phys. (U.S.S.R.) **32**, 614-615 (March, 1957)

A NATURAL mixture of neon isotopes contained in a fast acting Wilson cloud chamber under a pressure of 1.4 atm, was irradiated by γ-rays from the synchrotron up a to maximum energy of 80 Mev. The Wilson chamber was in a magnetic field of 5750 Oersted.

The following reactions were observed (a total of 719 cases): (γp), (γpn), $(\gamma 2p)$, $(\gamma 2\alpha)$, $(\gamma \alpha p)$ and $(\gamma 5\alpha)$. Reactions (γp) and (γpn) were distinguished by the pulse size and direction of the recoil nucleons, reactions (γp) and $(\gamma \alpha)$ were distinguished by the ionization density and the tracks of the recoil nuclei.

The orientation and length of tracks were determined by the reprojection method. The angular distribution (in the laboratory system of coordinates) of photoprotons from 1 to 15 Mev was studied. The dependence of the relative number of protons per unit solid angle on the angle θ between the direction of proton flight and the axis of the γ-ray beam is shown in the Figure in diagram form in 20° intervals. The angular distribution is well described by



a formula of the form $a + b\sin^2\theta$, where $b/a \approx 2.5$. The number of observed cases for the separate types of reactions is as follows:

Type of disintegration:	(γp)	(γpn)	$(\gamma 2p)$	$(\gamma 2\alpha)$	$(\gamma \alpha p)$	$(\gamma 5\alpha)$
Number of cases:	352	137	64	21	143	2

It should be noted that there is a substantial difference in the angular distributions of photoprotons for argon[1] and neon. Since the neon and argon nuclei are even-even, this difference cannot be due to the difference in nuclear spins but is apparently associated with the difference in the shell structures of the nuclei. The integral (γp) reaction cross section for neon determined relative to the (γp) reaction cross section for helium[2] turned out to be 0.16 ± 0.08 Mev-bn.

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