[12]One-boson-exchange models all seem to give low values of $\bar{\epsilon}_1$, near those of BS-III, LF, and Green (DSM) in Fig. 2. Thus an $\bar{\epsilon}_1$ standard deviation of 1.8° should distinguish between one-boson-exchange–type models and the others. The model of L. Ingber and R. M. Potenza, Phys. Rev. C 1, 112 (1970), discussed by K. Brueckner, in *Proceedings of the International Conference on Properties of Nuclear States, Montréal, Canada, 1969* (Presses de l'Université de Montréal, Montréal, Canada, 1969), predicts an $\bar{\epsilon}_1$ value which falls between those of LF and Green (DSM) in Fig. 2. Most of the increased nuclear binding of the Ingber model over those in the main cluster in Fig. 2 can be ascribed (Ref. 10) to this lower value of $\bar{\epsilon}_1$.

Inelastic Decay of Analog Resonances with Direct Reaction Background*

R. Arking, R. N. Boyd, J. C. Lombardi, A. B. Robbins, and S. Yoshida
Department of Physics, Rutgers, The State University, New Brunswick, New Jersey 08903
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A combination of direct (distorted-wave Born-approximation) and resonance scattering terms has been used to represent the reaction ^{124}Sn(p,p') to the 2^+ collective excited state in the region of the $\frac{7}{2}^-$ analog resonance at an incident energy of 10.65 MeV. Fits to on- and off-resonance cross sections and analyzing-power angular distributions have yielded spectroscopic information about the parent state in ^{125}Sn, represented as single-particle neutron states coupled to the 0^+ ground state and the 2^+ collective core state of ^{124}Sn.

Recently, investigations of inelastic proton scattering cross sections[1] and analyzing powers[2] through isobaric analog resonances (IAR) have been made in order to obtain information on the parent states. However, the extraction of detailed spectroscopic information was inhibited in these studies either by approximations made to handle the resonance-plus-background scattering, or by the lack of analyzing-power angular distributions. In this Letter, we report on measurements of off- and on-resonance cross sections and analyzing-power data for inelastic proton scattering to a collective excited state. These data were fitted by adding a Breit-Wigner term to the distorted-wave Born approximation (DWBA) scattering amplitude, thereby representing both the direct-reaction and resonance components of the scattering. Fitting these data has yielded spectroscopic information about weak-coupling states, the analogs of which we have observed.

The Rutgers-Bell tandem Van de Graaff accelerator was used in conjunction with the Rutgers metastable polarized ion source[3] to measure the cross section and analyzing-power data. Angular distributions were measured for scattering to the 2^+ state of ^{124}Sn which lies at 1.13 MeV excitation. Incident beam energies were 10.65 MeV, at which energy there exists a $\frac{7}{2}^-$ IAR,[4] and 10.00 MeV, which is an off-resonance energy.

The parent state for this resonance can be represented as an $f_{7/2}$ neutron coupled to the ^{124}Sn ground state $|C\rangle$, plus neutron single-particle states coupled to excited collective states of ^{124}Sn, giving the $\frac{7}{2}^-$ wave function

$$\Psi_{\text{par}} = \alpha|\nu_{7/2^-}\otimes C\rangle_{7/2^-} + \sum_{k,i}\beta_{ki}|\nu_k\otimes C_i{}^*\rangle_{7/2^-}.$$

The analog state results from the T^- operator acting on the parent state, and is given by

$$\Psi_{\text{Anal}} = \alpha(2T_0+1)^{-1/2}[|\pi_{7/2^-}\otimes C\rangle_{7/2^-} + (2T_0)^{1/2}|\nu_{7/2^-}\otimes A\rangle_{7/2^-}] + \sum_{k,i}\beta_{ki}(2T_0+1)^{-1/2}[|\pi_k\otimes C_i{}^*\rangle_{7/2^-} + (2T_0)^{1/2}|\nu_k\otimes A_i{}^*\rangle_{7/2^-}].$$

The first of the four analog terms represents a compound nuclear state which emits a proton from the $\frac{7}{2}^-$ level and leaves the residual nucleus in its ground state. The second term represents a nucleus which can have either neutron decay (although this is isospin forbidden to $T_<$ states) or proton decay. In the case of proton decay, the emitted proton will come from a level corresponding to a *filled* neutron level, and the residual nucleus will be a $\frac{7}{2}^-$ neutron coupled to a hole in that level of filled neutrons. The third term represents a nucleus which will decay via proton emission from level k, which must correspond to an unfilled level, and leave the residual nucleus in the excited collective state i. Proton decay of the fourth term is mostly to two-particle, two-hole configurations.

The decay to excited collective states, as indicated by the widths $\Gamma_{p'L_bJ_b}$, can be extracted by measuring angular distributions of (p,p') to these states and adequately accounting for the background. The widths can then be used to calculate spectroscopic factors $\mathcal{S}_n$. Care must be taken, however, in relating $\mathcal{S}_n$ to the coefficients β_{ki}, since mixing can occur between the second, third, and fourth terms of the analog-state wave function. This mixing is a result of the collective state really being a linear combination of particle-hole states, so that the residual particle-hole configurations represented by these terms can be quite similar. The 2^+ collective state is mostly a one-particle, one-hole configuration[5] so that the fourth term can be neglected. The second term can be neglected either if the collective state is composed solely of proton particle-hole excitations, or if the emitted proton is from a level corresponding to an empty neutron level in the target nucleus. In the even tin nuclei, the protons form a closed shell, so that it is likely that neutron particle-hole excitations are important contributions to the 2^+ collective state. Therefore, only if the second condition holds can we determine β_{ki}. If the proton is emitted from a level corresponding to a partially filled neutron level, then the two terms may interfere and, as a result, no conclusion can be made regarding β_{ki}.

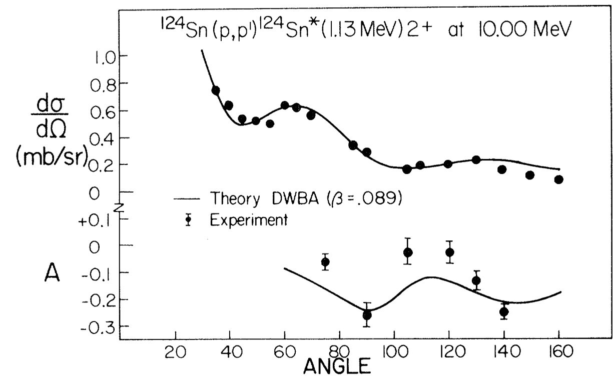

FIG. 1. DWBA fit to off-resonance cross-section $(d\sigma/d\Omega)$ and analyzing-power (A) data using optical-model parameters from elastic-scattering analyses.

Since the (p,n) threshold for ^{124}Sn ($Q_{pn} = -1.5$ MeV) is well below the energy region in which we are working, it should be valid to ignore the effects of Hauser-Feshbach compound nuclear scattering. The measured off-resonance cross sections agree very well with the DWBA predictions (see Fig. 1), thus validating this assumption. Hence the observed scattering should be well represented by a combination of direct inelastic and resonance terms, as outlined by Lane and Thomas.[6] We have modified the DWBA code DWUCK[7] to provide such a representation. This involves adding a Breit-Wigner resonance term to the DWBA collision function $U_{\alpha'I'J_b,\alpha 0 J_a}{}^{J\,\mathrm{dir}}$ to give the total scattering amplitude as

$$A_{\alpha'I'S'm_I'm_S',\alpha 0 s 0 m_s} = -\frac{i}{2k_\alpha}\sum_{L_aJ_aL_bJ_b}[(2L_a+1)(2L_b+1)]^{1/2}\langle L_aS0m_s|J_aM_a\rangle\langle L_bS'0m_{s'}|J_bM_b\rangle \times\langle J_bI'M_bm_{I'}|JM\rangle d_{MM_b}{}^{J_b}[U_{\alpha'I'J_b,\alpha 0J_a}{}^{J\,\mathrm{dir}}+U_{\alpha'I'J_b,\alpha 0J_a}{}^{J\,\mathrm{res}}],$$

where

$$U_{\alpha'I'J_b,\alpha 0J_a}{}^{J\,\mathrm{res}} = (-1)^{L_a+L_b+S+S'-J_a-J_b+1}\exp[i(\delta_\alpha{}^R+\delta_{\alpha'}{}^R+\omega_\alpha+\omega_{\alpha'}+\varphi_R+\varphi_{RL_bJ_b}{}')] \times(\Gamma_p\Gamma_{p'L_bJ_b})^{1/2}(E-E_R+i\Gamma/2)^{-1}.$$

The incident (exit) particle spin is represented by S and m_S (S' and m_S'), the initial (final) target spin by 0 and 0 (I' and m_I'); and α and α' represent incident and exit particle energy, respectively. The angular-momentum coupling scheme used is illustrated for the exit channel: The particle spin $\vec{S}'$ and orbital angular momentum $\vec{L}_b$ were coupled to $\vec{J}_b$, which was then coupled to residual nuclear spin $\vec{I}'$ to give total angular momentum $\vec{J}$ having projection M. The quantity $d_{M,M_b}{}^{J_b}$ is the rotation matrix.[8]

In the resonance term, $\delta_a{}^R$ and $\delta_b{}^R$ are incoming and outgoing channel nuclear phase shifts, respectively, and ω_a and ω_b are the Coulomb phase shifts. The elastic and inelastic resonance mixing phases are given by φ_R and $\varphi_{RL_bJ_b}{}'$, respectively. The parameters Γ_p, $\Gamma_{p'L_bJ_b}$, E_R, and Γ are, respectively, the total proton width, partial inelastic proton width in channel (L_b, J_b), resonance energy, and total resonance width. Note that the quantity $(\Gamma_p\Gamma_{p'L_bJ_b})^{1/2}$ can be positive or negative, depending on the relative phase of the proton reduced width and amplitudes. Note that the resonance term is summed over all the single-particle waves which couple to the core to give the spin and parity of the IAR. In addition, the resonance term was energy averaged[9] over the target thickness.

Figure 1 shows the measured cross sections and analyzing powers at the off-resonance energy of 10.00 MeV for the proton inelastic scattering to the 2^+ state of ^{124}Sn. The fits were calculated using the DWBA code DWUCK.[7] The optical-potential parameters chosen were interpolated from the optical-model parameters which give best fits to off-resonance elastic cross-sections and polarization angular distributions[10] in this energy region. Thus, the only parameter adjusted for the off-resonance inelastic fits was the deformation parameter. The value obtained for this parameter is 0.089, in reasonable agreement with the value obtained for 16.00-MeV proton scattering.[11]

The measured on-resonance angular distributions and their fits are shown in Fig. 2. The fits were determined by gridding over the values of the various $\Gamma_{p'L_bJ_b}$ to determine the best simultaneous fit to the inelastic cross section and analyzing-power data. The elastic resonance parameters were taken from the ^{124}Sn(p,p_0) analysis[10] and were $\Gamma = 82.9$ keV, $\Gamma_p = 23.7$ keV, and $\varphi_R = 6.3°$.

Also included in Fig. 2 are the angular distributions which would result for pure $p_{3/2}$ and pure $f_{7/2}$ neutron single-particle states coupled to the 2^+ core excitation. These two curves exhibit oscillations typical of those seen in all of the single-partial-wave angular distributions. Since the differences between predictions with various partial waves are considerably greater for the analyzing powers than for the cross sections, accurate analyzing power data are essential to the precise determination of the separate $\Gamma_{p'L_bJ_b}$.

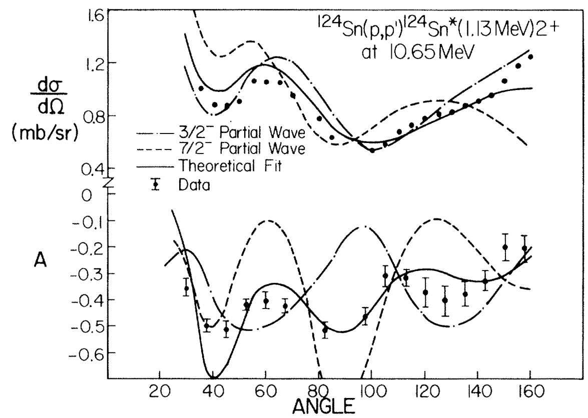

FIG. 2. Best fit to on-resonance data obtained by adding resonance terms to the DWBA.

The best fit to the data was obtained using the widths $\Gamma_{p'L_bJ_b}$ which are given in Table I along with the relative phases of the reduced widths. Spectroscopic factors $\mathcal{S}_n$ were calculated using the method of Thompson, Adams, and Robson[12] with the computer code SSEARCH.[13] The mixing phases $\varphi_{RL_bJ_b}'$ were also calculated with this code and used in the modified version of DWUCK to obtain the best fits. The coefficients α and β_{ki} were obtained by taking the square root of $\mathcal{S}_n$.

The importance of direct scattering in calculating the analyzing power at a resonance is evident by the large values of analyzing power observed (~0.5); these would be zero in the absence of direct scattering.[14] Thus, we see that by fitting both cross section and analyzing-power angular distributions with an accurate representation of direct and resonance inelastic scattering, useful spectroscopic information is obtained.

TABLE I. Widths for the decay of the $\frac{7}{2}^-$ resonance at 10.65 MeV in ^{125}Sb to the 2^+ collective state in ^{124}Sn obtained from the best fit to the data.

Residual state	L_b	J_b^π	Relative phase	$\Gamma_{p'L_bJ_b}$ (keV)	$\varphi_{RL_bJ_b}$ (deg)	$\mathcal{S}_n$	α	β_{ki}
0^+, g.s.	3	$\frac{7}{2}^-$	+	23.7 ± 1.8	6.3	0.56	+0.75 ± 0.09	...
	1	$\frac{3}{2}^-$	−	0.55 ± 0.15	10.3	0.012	...	−0.11 ± 0.02
2^+, 1.13 MeV	3	$\frac{5}{2}^-$	−	0.40 ± 0.15	8.8	0.018	...	−0.13 ± 0.03
	3	$\frac{7}{2}^-$	−	0.55 ± 0.15	7.6	0.022	...	−0.15 ± 0.03
	5	$\frac{9}{2}^-$	−	0.30 ± 0.10	6.2	0.31	...	−0.56 ± 0.10
	5	$\frac{11}{2}^-$		0.00 ± 0.10	11.3	0.00	...	...

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New Theory of Gravitation

Hüseyin Yilmaz
Perception Technology Corporation, Winchester, Massachusetts 01890
(Received 2 June 1971)

A locally Lorentz-invariant curved-space theory of gravitation where the local field is a massless, spin-2 field $\varphi_\mu{}^\nu$ of Pauli-Fierz type is presented. In this theory $g_{\mu\nu}$ is no longer the gravitational potential itself but reduces to a functional $g_{\mu\nu}(\varphi_\alpha{}^\beta)$ of $\varphi_\mu{}^\nu$. Several rigorous and a general iteration solution of this type are exhibited. The static central body problem reduces exactly to author's 1958 theory in the special case $\varphi_\mu{}^\nu \to \varphi_0{}^0 = \varphi$ and $\partial^\mu \varphi_\mu{}^\nu \to \partial^0\varphi = 0$ so that as in that theory the three crucial tests are satisfied.

About ten years ago there existed at least seven, more or less plausible, theories of gravitation. Three of these were the flat-space theories of Poincaré, Whitehead, and Birkhoff. In the curved-space category were the theories of Einstein, Jordan, Brans-Dicke, and the author, Einstein's theory being of course the most prominent among them. In 1961 with the measurement of gravitational red shift in earthbound laboratories it became clear that the flat-space theories have to be abandoned.[1] This situation led, since 1961, to a vigorous development of Jordan and Dicke type theories (Brans-Dicke theory in fact belongs to a class of Jordan theories) and until recently Brans-Dicke theory was considered quite seriously in many quarters.

In the fall of 1970, however, the experiment on the time delay of radar signals reflected from Venus and Mercury reached accuracies high enough to permit at least a preliminary judgement against the Jordan and Brans-Dicke type of theory.[2] If the present trend of results continues, the 1916 theory of Einstein and the largely undeveloped 1958 theory of the present author will probably be the only two generally known and experimentally viable theories of gravitation.[3] On the other hand the 1958 theory of the author, as published, has the theoretically objectionable feature that it does not possess time-dependent dynamic solutions. This of course casts serious doubts on the validity of this theory leaving Einstein's 1916 theory practically unrivaled. We are therefore motivated to present a natural extension of our 1958 theory which seems to open a new and interesting avenue of inquiry as well as avoiding the above mentioned objection.

Formulation of the theory.—One of the main differences between Einstein's theory and the present theory of gravitation is that in Einstein's theory the components of the metric tensor $g_{\mu\nu}$ are considered as the components of the gravitational potential and are therefore functions of