ping to the first excited state of ^{53}Cr ($l = 1$, $j = \frac{1}{2}$) is well reproduced, including the strong dip at 130°. Potentials using surface absorption in the deuteron channel improve the cross-section fit for the ground-state transition, but then the fit to $P_p{}^r$ is quite poor.

This investigation has shown that it is possible to obtain potentials which describe at the same time the elastic scattering cross section and polarization as well as the reaction vector analyzing power and proton polarization. The reasons for the success of these particular optical-model potentials is not well understood. More work needs to be done to determine the relationship between the optical-model parameters and proton-polarization predictions.

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WHY DOES ^{56}Ni DECAY SO SLOWLY?*

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The decay of the doubly magic nucleus ^{56}Ni to the lowest 1^+ state of ^{56}Co proceeds about a hundred times slower than the shell model predicts. The explanation is that the lowest 1^+ state of ^{56}Co is mostly a two-particle, two-hole state. The giant spin-isospin resonance lies at a higher energy.

The ground state of the doubly magic nucleus ^{56}Ni decays by K capture to the lowest 1^+ state of ^{56}Co, which has an excitation energy of 1.72 MeV. The transition rate is characterized by a $\log_{10}ft$ which is[1] about 5 – not a usual value for an allowed Gamow-Teller transition.

We first point out that a shell-model calculation of this decay gives a unique answer provided the following assumptions are made: (a) ^{56}Ni is a doubly closed shell. (b) The lowest 1^+ state of ^{56}Co is a one-particle, one-hole (1p-1h) state.

The only 1p-1h state with spin 1 is $[f_{7/2}{}^{-1}(\pi)f_{5/2}(\nu)]$. This state can be called the giant spin-isospin state, since precisely this state results when one operates with the Gamow-Teller operator, $\sum_i \sigma_i t_{+i}$, upon the shell-model ground state of ^{56}Ni. Rarely can a giant resonance state be described as a simple j-j coupling state. Thus, the unique initial and final states yield

$$M_{\mathrm{GT}}^2 = 96/7,$$

which gives a $\log_{10}ft$ of 2.5. The M_{GT}^2 is so large (it is only 3 for a free neutron) because there are eight $f_{7/2}$ protons, each of which can be changed into an $f_{5/2}$ neutron.

Since there is such a large discrepancy, one or both of the above assumptions must be wrong. One can test whether they are slightly wrong by improving the initial and final states using first-order perturbation theory. Thus, 2p-2h components will be admixed in both ^{56}Ni and ^{56}Co wave functions, but the result will only depend on the ^{56}Ni admixture since the 0p-0h component of the ^{56}Ni ground state cannot decay to the 2p-2h component of ^{56}Co. The ^{56}Ni wave function is

$$|\psi^{0+}(^{56}\mathrm{Ni})\rangle = |0\rangle + \sum_{I_A T_A} b(I_A T_A)[(f_{\frac{7}{2}}^{-1} f_{\frac{7}{2}}^{-1})^{I_A T_A}(f_{\frac{5}{2}} f_{\frac{5}{2}})^{I_A T_A}]^{00}\rangle + \text{other configurations},$$

where

$$b(I_A T_A) = -[(2I_A+1)(2T_A+1)]^{\frac{1}{2}} \langle (f_{\frac{5}{2}} f_{\frac{5}{2}})^{I_A T_A} | (V/\Delta E) | (f_{\frac{7}{2}} f_{\frac{7}{2}})^{I_A T_A} \rangle$$

and $\Delta E \simeq -12$ MeV is minus twice the $f_{5/2}$-$f_{7/2}$ single-particle splitting. We find

$$M_{\mathrm{GT}}^2 = (96/7)[1 + 0.083b(0,1) - 0.240b(1,0) + 0.163b(2,1) - 0.286b(3,0) + 0.145b(4,1) - 0.174b(5,0)]^2.$$

Using the two-body matrix elements of Kuo and Brown[2] we find that all terms contribute coherently, but even so the correction is not very large,

$$M_{\mathrm{GT}}^2 = (96/7)[1.0 - 0.17]^2,$$

which yields a $\log_{10}ft$ of 2.68. The discrepancy remains.

The next step, and this proves to be the most fruitful, is to diagonalize the two-body Hamiltonian in the space of 0p-0h and 2p-2h for ^{56}Ni and 1p-1h and 2p-2h for ^{56}Co. The single-particle energies used were $\epsilon_{f_{7/2}} = 0$, $\epsilon_{p_{3/2}} = 4.85$, $\epsilon_{f_{5/2}} = 5.63$, and $\epsilon_{p_{1/2}} = 5.97$. $\epsilon_{p_{3/2}} - \epsilon_{f_{7/2}}$ was obtained by averaging the proton single-particle energy (determined from the binding energies of ^{56}Ni, ^{57}Cu, and ^{55}Co) and the neutron single-particle energy (determined from the binding energies of ^{56}Ni, ^{57}Ni, and ^{55}Ni). The remaining single-particle energies were determined from the spectrum of ^{57}Ni. Our single-particle energies are much larger than those used by Wong and Davies,[3] and consequently we get much more conservative, but in our opinion more meaningful, results. The Kuo-Brown[2] matrix elements for ^{40}Ca (not ^{56}Ni) were used.

The ^{56}Ni ground state obtained by matrix diagonalization is quite close to the perturbation theory result, with the amount of 2p-2h admixture being 26%.

The big change was in ^{56}Co where it is found that the lowest 1^+ state was not the 1p-1h state but rather was an almost pure 2p-2h state. It came at 1.27 MeV while six other 2p-2h 1^+ states intervened before the giant spin-isospin state appeared at 3.80 MeV. The wave function of this lowest state is

$$|\psi^{1^+}(^{56}\mathrm{Co})\rangle = 0.016 f_{7/2}^{-1}(\pi) f_{5/2}(\nu) + 0.71 (f_{7/2}^{-2})^{J=0,\,T=1} (p_{3/2} p_{1/2})^{J=1,\,T=0}$$

$$-0.46 (f_{7/2}^{-2})^{J=0,\,T=1} (p_{3/2}^{2})^{J=1,\,T=0} + 0.32 (f_{7/2}^{-2})^{J=0,\,T=1} (p_{3/2} f_{5/2})^{J=1,\,T=0} + \cdots.$$

This state is close to a spin-1 pairing vibration state. The corresponding $\log_{10}ft$ is 5.8, and it is due almost entirely to decay to the giant spin-isospin part of this 1^+ state in ^{56}Co.

This result has been anticipated by several authors. The people who did the K-capture experiment[1] also did a 1p-1h calculation and found that of the six spin states that could be formed from $[f_{7/2}^{-1}(\pi)f_{5/2}(\nu)]$, the "outside ones" $J=1^+$ and $J=6^+$ lay the highest. Thus, one could not associate the 1.72-MeV state with this configuration without having a second $J=2^+$, 3^+, 4^+, and 5^+ multiplet at a lower energy {the first such multiplet is $[f_{7/2}^{-1}(\pi)p_{3/2}(\nu)]$ which includes the ground state of ^{56}Co}. This second multiplet below 1.72 MeV has not been observed. Also, Vervier[4] concluded that this state should have less than 1% of the $[f_{7/2}^{-1}(\pi)f_{5/2}(\nu)]$ configuration to be consistent with the ^{56}Ni decay.

Two-nucleon transfer data also suggest that this state is basically 2p-2h. We refer to the work of Laget and Gastebois,[5] who performed the ^{54}Fe(^{3}He,p)^{56}Co and ^{58}Ni(d, α)^{56}Co experiments. In the first reaction the 1^+ state is seen very strongly. This agrees with the presence of a large component on the wave function of the form

$$|[(f_{7/2}^{-1}f_{7/2}^{-1})^{J=0,\,T=1} \times (P^2)^{J=1,\,T=0}]^{j=0,\,t=1}\rangle.$$

This is because the ground state of ^{54}Fe can be viewed as $|[f_{7/2}^{-1}(\pi)f_{7/2}^{-1}(\pi)]^{J=0}\rangle$. In addition, in a two-nucleon transfer reaction there is a large enhancement when the two nucleons go into the p shell as compared with the f shell. The 1^+ state is not seen so strongly in the second reaction which, presumably, is sensitive to admixtures such as

$$|[(f_{7/2}f_{7/2})^{J=1,\,T=0}(P^2)^{J=0,\,T=1}]^{j=1,\,t=1}\rangle.$$

In the calculated wave function of the lowest lying 1^+ state in ^{56}Co, these terms make little contribution.

The strong hindrance of the Gamow-Teller transitions appears to be a global property, not confined to ^{56}Ni. Many examples have been found and studied in heavier nuclei.[6]

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CHEMICAL COMPOSITION OF PRIMARY COSMIC RAYS AT 10^{15} eV*

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An analysis of the nuclear-active particle component of extensive air showers has yielded evidence that the chemical composition of primary cosmic rays at 10^{15} eV cannot consist solely of protons or solely of very heavy nuclei. The data are consistent with the mixed composition observed at lower energy (~10^{11} eV).

The chemical composition of primary cosmic rays of energy greater than 10^{14} eV is of astrophysical interest and must be determined indirectly from extensive air showers (EAS) because of the small flux of these primaries incident on the earth's atmosphere. In an earlier work[1] (hereafter [I]) we demonstrated a strong theoretical relationship between the composition of primaries at these energies and the extent of fluctuations in the total energy of the nuclear-active component of the associated EAS. In the present communication, we use this result and data from a large-area nuclear-active particle (n.a.p.) detector of the Bolivian Air Shower Joint Experiment (BASJE) to derive information about the composition of primaries at 10^{15} eV.

At energies up to 10^{12} eV the chemical composition of the primaries has been determined from balloon-borne emulsions to be approximately 49% H, 26% He, 2% Li + Be + B, 11% medium Z ($6 \leq Z \leq 9$), 5% heavies ($10 \leq Z \leq 19$), and 7% very heavies ($Z \geq 20$).[2] The Soviet satellites Proton 1 and Proton 2 have recorded data which suggest that the proton component of the primaries is decreasing rapidly above 10^{12} eV.[3] Above 10^{14} eV the composition is not well known although several groups[4-10] have drawn conclusions from considerations of the n.a.p., Cherenkov light, and