in light nuclei;[6] if we take (2+), we have $E2$ radiation with $(2J+1)\Gamma_\gamma = 250$ or 1250 ev and $(2J+1)|M|^2 = 135$ or 675, which seems improbable. (1−) is therefore the most plausible assignment; it is made almost certain by the angular distribution of the alpha-particles (A. V. Cohen and A. P. French, private communication). If we are correct in the identification and assignment, we have a breakdown of the isotopic spin and charge parity rules; the emission of alpha-particles demands here $T=0$, even charge parity, while the emission of $E1$ radiation demands here $T=1$, odd charge parity;[1,2,7] yet both widths are large ($\Gamma_\gamma = 150$ ev; $\Gamma_\alpha = 75$ kev) and neither may be supposed to have suffered a very large measure of discouragement. We may not rule out the possibility that there are two resonances and that what we are observing is the rules in action rather than their violation, though this seems unlikely in view of the agreement in position and width. The excitation in O^{16} is 13.1 Mev and the first $T=1$ level may be expected at about 12.5 Mev.[8]

The reaction $B^{11}(p,\alpha)Be^8$ (ground state) is resonant at somewhat over 1 Mev[9] in proton energy; $B^{11}(p,\gamma)C^{12}$ (ground state) is strongly resonant at 1.4 Mev[10] with a large radiative width. This may be a similar example but is not so clear-cut. The reactions $Be^9(p,\alpha)Li^6$ and $Be^9(p,d)Be^8$ are resonant at 0.94 Mev,[11] while $Be^9(p,\gamma)B^{10}$ has a strong, almost certain, $E1$ resonance of similar width at 0.998 kev;[12] but these may well involve two different states. In these last two examples we are in a region of excitation containing $T=1$ states.

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The Purity of Isotopic Spin or Charge Parity States

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We have carried out two experiments to attempt to assess the purity of isotopic spin or charge parity states[1–3] of moderate excitation.

O^{16} possesses[4] a (1−) state at 7.12 Mev, a (2+) state at 6.91 Mev, a (3−) state at 6.14 Mev and a (0+) state at 6.05 Mev; the ground state is (0+). All these states are expected[5] to have $T=0$; if we think in terms of charge symmetry alone, the charge parity is probably even. The (1−) state decays to the ground state thereby violating the isotopic spin[6] or charge parity[7] rule. The $E2$ decay to the (3−) state is uninhibited by the special rules; we have shown it to occur at least 120 times less probably than the forbidden $E1$ transition. We have also shown that the (2+) state decays to the ground state at least 200 times more readily than to the (3−) state, although, in the absence of the special rules this latter $E1$ transition would be preferred. The single-particle matrix elements[8] seem to be unexpectedly reliable[9] for the prediction of $E1$ radiative widths, and there is no evidence that they are grossly wrong for $E2$ transitions in light nuclei; if we apply them to this case, we obtain the result that the contamination of the (1−) state is more than 0.2 percent in *amplitude* and that that of the (2+) and (3−) states is less than 3 percent in amplitude (assuming the ground state to be pure $T=0$). These estimates are probably reliable to a factor of five or better.

The first state with $T=1$ in B^{10} is at 1.74 Mev; the first excited state of Be^{10} is at 3.37 Mev and is (2+). A doublet exists in B^{10} at 5.11 and 5.16 Mev; there is another state at 4.8 Mev. It seems that one member of the doublet should have $T=1$. We have measured the excitation function of the reaction $Li^6(\alpha,\gamma)B^{10}$. We locate the lowest state at 4.75 ± 0.02 Mev ($\omega\Gamma\sim0.15$ ev) and the upper element of the doublet at 5.162 ± 0.008 Mev ($\omega\Gamma\sim0.2$ ev), but we find no trace of the 5.11-Mev level ($\omega\Gamma<\sim0.004$ ev). The obvious explanation, that the 5.11-Mev state has $T=1$ and its formation is inhibited by the isotopic spin rule, is rendered unlikely by the implied "discouragement factor" of more than 2×10^4 (if we guess an "uninhibited" width of about 100 ev for the $l=2$ alpha-particles of 1.1 Mev), Radicati[10] having calculated that there is probably about 0.25 percent in *intensity* of $T=1$ in the ground state of Li^6.

It is then possible that the 5.16-Mev level has $T=1$ with an implied discouragement factor of order 500, which is consistent with Radicati's estimate. It is known[11] that one or other element of the doublet is (1−) or (2−); (1−) we cannot admit, as the $E1$ transition to the lower $T=1$ level (0+) would be allowed. We therefore suggest that this 5.11-Mev level may be (2−) and would then see in its small width the operation of the isotopic spin selection rule on $E1$ transitions [the ground and first excited states of B^{10} are (3+) and (1+), respectively]; we would then be on fairly safe ground in inferring a contamination of less than 2 percent in *amplitude* (assuming the lower states to be pure $T=0$).

These observations of two possible violations and two possible successes of the pure isotopic spin or charge parity selection rules seem to accord with what might be expected from complete specifically nuclear charge independence or charge symmetry when the effect of the Coulomb perturbation is taken into account.

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Angular Distribution of γ-Rays from Stripping Reactions

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The angular distribution (about the recoil axis) of the γ-radiation following a deuteron-stripping reaction has been treated both in terms of the channel spin of the capture process[1,2] and in terms of the total angular momentum j of the captured particle.[3]

Stripping reactions enable nucleons to be captured into low-lying excited levels where the Mayer $j-j$ coupling scheme is

Table I. γ-ray angular distributions predicted by the shell model. J_i = spin of initial nucleus; j = total angular momentum (spin+orbital) of captured particle; J_e = spin of excited nucleus after capture; L = multipole order of γ-ray; J_f = nuclear spin after emission.

J_i	(j)	J_e	(L)	J_f	A_2	A_4
0	(3/2)	3/2	(1)	1/2	−0.500	···
			(1)	3/2	+0.400	···
			(1)	5/2	−0.100	···
			(2)	7/2	+0.143	···
0	(5/2)	5/2	(1)	3/2	−0.400	···
			(1)	5/2	+0.457	···
			(1)	7/2	−0.143	···
			(2)	1/2	+0.571	−0.571
3/2	(3/2)	2			Isotropy*	
5/2	(5/2)	2	(2)	0	−0.204	−0.367
5/2	(5/2)	4	(2)	2	+0.160	+0.139

* Isotropy in this case is a numerical coincidence.