Coulomb Breakup of ^{15}C and ^{17}C B,G

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Coulomb breakup of secondary beams of unstable nuclei at intermediate energies has developed into a standard spectroscopic tool in exploring properties of weakly bound nuclei. Here, this method has been applied to a study of ^{15}C and ^{17}C isotopes wich have very small neutron separation energies of 1.2 and 0.73 MeV, respectively.
Radioactive beams of ^{15,17}C were produced in a fragmentation reaction of a primary ^{40}Ar beam, delivered by the synchrotron SIS at GSI, Darmstadt, and were subsequently separated in flight by the FRS. The incoming beam was identified utilizing energy-loss and time-of-flight measurements together with the known magnetic rigidity. Likewise, the nuclear charge, velocity, scattering angle, and the mass of the fragments emerging from a reaction target were determined. Neutrons and γ-rays were detected by the LAND and Crystal Ball spectrometers, respectively. From the measured momenta of all decay products of the projectile after inelastic scattering followed by breakup, the excitation energy of the nucleus was determined. The Coulomb dissociation cross sections with the Pb (1.8 g/cm^2) target were obtained after subtracting nuclear contributions determined from the data with a C (0.573 g/cm^2) target.
By comparing measured differential cross sections $d\sigma/dE^*$ (excitation energy E^*) for electromagnetic excitation with calculated cross sections (see below) one can deduce information on the ground state structure. The Coulomb breakup cross section can be written [1]:

$$\frac{d\sigma}{dE^*} = (\frac{16\pi^3}{9\hbar c})N_{E1}(E^*)\,|< q \mid (Ze/A)rY_m^l \mid \psi(r) >|^2\,. \quad (1)$$

$N_{E1}(E^*)$ represents the number of equivalent dipole photons of the target Coulomb field, computed in a semiclassical approximation, ψ(r) represents the ground state single particle wave function of the neutron and $< q \mid$ describes the wavefunction of the neutron in the continuum. If, for simplicity, the latter is replaced by a plane wave, the matrix element in equ. (1) evidently reflects the Fourier transformed projectile ground state weighted by the radial coordinate r. The measured Coulomb breakup cross section may thus be used to determine, for example, spectroscopic amplitudes of ground state (g.s.) components.

In the case of ^{15}C with the known g.s. spin I$^\pi$ = $1/2^+$, the experimental data show that Coulomb breakup populates predominatly the ground state of ^{14}C, a small branch of about 10 % feeding excited states at 6 - 7 MeV is observed in addition. The analysis of $d\sigma/dE^*$ for the ground state of ^{14}C according to equ. (1) delivers a spectroscopic factor for a neutron in the s orbital which is consistent with an earlier result [3].

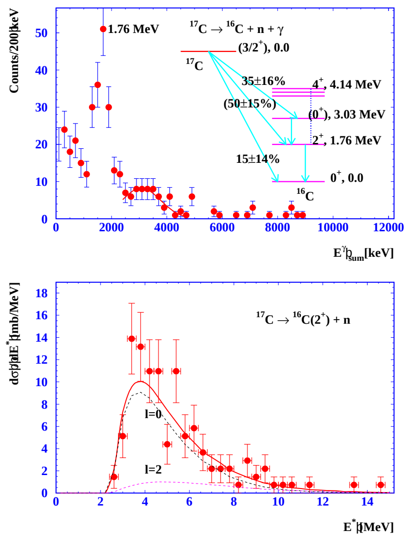

Fig. 1: Sum energy of γ decay transitions (top).
Differential Coulomb dissociation cross section (bottom).

The ground state spin of ^{17}C is not fully established experimentally. Our experimental data for Coulomb break up of ^{17}C show that most of the cross section yields the ^{16}C core in its first excited state, I$^\pi$= 2^+, and an excited state at an excitation energy around 3 MeV. Only a small part of the cross section leaves the core in its ground state. Fig. 1 (top) shows the sum energy spectra of the γ decay from ^{16}C fragments and indicates the relative partial cross sections for the population of different core states. The lower part of the Fig. 1 shows $d\sigma/dE^*$ for electromagnetic excitation of ^{17}C in coincidence with the 1.766 MeV γ transition ^{16}C($2^+ \rightarrow 0^+$) without acceptance and efficiency corrections for the neutron detector. These corrections, however, are taken into account in the cross sections calculated according to equ. (1). A proper choice of relative contributions from l = 0 and l = 2 neutrons forming the ^{17}C g.s. wave function, as shown Fig 1, can reproduce well the data. Thus, ^{16}C(2^+)$\bigotimes \nu_{s,d}$ can be considered as the predominant g.s. configuration. Due to the occupation of the $s_{1/2}$ neutron orbital, one can rule out a $1/2^+$ ground state spin of ^{17}C, leaving I$^\pi$ = $3/2^+$ and $5/2^+$ as the possible spins assignments. Concerning the respective spectroscopic factors, the major part of our results is in agreement with those from a different method, i.e. obtained from a knockout reaction [4].

References

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