JYFLTRAP : Q-Values of the Superallowed Decays of $^{26}Al^{m}$, ^{42}Sc and ^{46}V

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A new collaboration has been formed based on the JYFLTRAP at the University of Jyväskylä cyclotron facility. As with our CPT collaboration, the goal of this group is to measure atomic masses related to superallowed β decay. Since a recent measurement by the Canadian Penning Trap (CPT) Mass Spectrometer [1] reported a result for the Q_{EC} value of the superallowed transition from ^{46}V that disagrees significantly with previous reaction-based measurements, concern has arisen that there might be undetected systematic errors either in the reaction measurements or in the on-line Penning-trap ones [2]. If this were the case, it could potentially lead to a significant shift in the value of V_{ud} extracted from the superallowed decays [3]. Although masses are ultimately measured at JYFLTRAP with a Penning trap, the production beams, delivery system and many other aspects of that system are quite different from those at the CPT facility. If measurements from both systems prove to be in agreement with one another, then at least some potential sources of systematic errors can be eliminated.

So far, we have completed measurements of the Q_{EC} values for $^{26}Al^{m}$, ^{42}Sc and ^{46}V and have prepared a manuscript for publication [4]. All ions of interest were produced at the IGISOL facility. We produced ^{46}V and $^{26}Al^{m}$ via (p, n)-reactions, with 20- and 15-MeV proton beams incident on enriched ^{46}Ti and ^{26}Mg targets respectively. For ^{42}Sc, we used a ^{3}He beam of 20 MeV on natural calcium. In these bombardments, not only were the superallowed emitters of interest produced in the primary reactions but ions from the target material itself – the beta-decay daughters of these emitters – were also released by elastic scattering of the cyclotron beam. All recoil ions were slowed down and thermalized in the gas cell of an ion guide filled with 150 mbar of helium. These ions were then transported by gas flow and electric fields through a differentially pumped electrode system into a high-vacuum region, accelerated to 30 keV and passed through a 55^{o} dipole magnet for a coarse mass selection with resolving power of 300-500.

The mass-separated ion beam was then transferred to the JYFLTRAP setup, which consists, first, of a radio-frequency quadrupole (RFQ) cooler used to improve the quality of the beam and bunch it for efficient injection into the Penning-trap system. The latter consists of two cylindrical traps housed inside the same superconducting 7-T magnet. The first trap is filled with helium buffer gas to allow for purification of the ion sample (mass resolving power up to a few times 10^{5}). The second Penning trap is where the actual mass measurement is made. A dipole excitation is used to establish a magnetron orbit with a fixed frequency and amplitude. Then, the ion cloud is exposed to a radiofrequency quadrupole electric field for a given time. The amplitude of the RF electric field is tuned so that, when the frequency corresponds to the cyclotron frequency of the ion of interest, the whole magnetron motion is converted to cyclotron motion. After the quadrupole excitation, the ions are extracted from the trap and their time-of-flight to a micro channel plate detector recorded. The frequency corresponding to the shortest time-of-flight is the true cyclotron frequency. To locate the precise resonance frequency, we scanned the frequency and recorded the time of flight over a range that spanned the resonance.

The Q_{EC} value of each ion of interest was obtained directly from the frequency ratio of the mother and the daughter nuclei. The cyclotron frequency measurements were interleaved: first we recorded a frequency scan for the daughter, then for the mother, then for the daughter and so on. This way, the slow drift of the magnetic field, mostly due to drifts in the room temperature, could be treated properly by interpolation of the reference frequency to the time of measurement for the ion of interest. For each measurement, data were collected in several sets, each comprising ~10 pairs of parent-daughter frequency scans taken under the same conditions. Between sets, the excitation time was changed. Each of the resonance curves was fitted with a realistic function, which yielded values for the resonant frequency and its statistical uncertainty. Our results are given in Table I.

Table I. Q_{EC} values obtained from this measurement, compared with values from our 2005 survey of world data [3], and our subsequent CPT measurement [1].

Parent nucleus	Present result	2005 Survey value [3]	Savard *et al.* [1]
$^{26}Al^m$	4232.83(13)	4232.55(17)	--
^{42}Sc	6426.13(21)	6425.63(38)	--
^{46}V	7052.72(31)	7050.71(89)	7052.90(40)

There are three important conclusions we can draw from our results. First, we confirm our recent CPT measurement [1] of the ^{46}V Q_{EC} value, which disagrees with the previously accepted value [3]. The latter was a survey result principally based on a 30-year-old (^3He,t) Q-value measurement by Vonach et al. [5]. Second, since our results for $^{26}Al^m$ and ^{42}Sc agree well with the survey values, we can effectively rule out widespread systematic differences of more than ~100 eV between reaction-based Q-value measurements and those obtained with an on-line Penning trap (see ref. [2] for an elaboration of this point). Finally, we can conclude that no significant shift in the value of V_{ud} should be anticipated as more and more on-line Penning-trap measurements of the superallowed Q_{EC} values become available. Apparently ^{46}V was an anomalous case, for which only a single dominant measurement had previously been available [5], a measurement that appears simply to have been wrong.

We plan to continue these measurements to other superallowed decays.

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