Q-Value for the Fermi Beta-Decay of ^{46}V

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Pure Fermi beta-transitions between Isobaric Analog States (IAS) yield (besides neutron decay) the value of the matrix element V_{ud} of the Cabibbo-Kobayashi-Maskawa matrix. Experimental values needed with great precision are the (partial) half life and the phase space factor where the decay energy enters with the fifth power. Recently the decay energy of ^{46}V has been measured by direct mass measurements [1] of ^{46}V and ^{46}Ti in the Canadian Penning Trap at Argonne National Laboratory. This new result is at variance with the 1977 result obtained in our laboratory by Vonach *et al.* [2] who measured the Q value of the ^{46}Ti(^{3}He,t)^{46}V reaction. Savard *et al.* argue that all seven Q-values of Vonach *et al.* [2] are erroneous and discard them in the averages of input data. Since they regard reaction Q-value measurements in general with scepticism, we repeated the (^{3}He,t) measurement to clarify, whether there is a principal problem.

A negative ^{3}He beam from the ECR source [3] was accelerated in the Munich MP tandem accelerator to an energy of 27 MeV. Typical beam currents of $^3He^{2+}$ ions on target were 0.8 μA. The beam energy was chosen as a compromise for optimum energy resolution. The triton energy from the ^{46}Ti(^{3}He,t)^{46}V reaction was (as in [2]) measured with the Munich Q3D magnetic spectrograph, that provides a superb intrinsic energy resolution of about $2\cdot10^{-4}$. In the focal plane the position was measured by a gas proportional detector with individual readout of 256 cathode strips [4]. The more than 100 m long TOF measurement used by Vonach *et al.* to calibrate the beam energy and the spectrograph is not operational any more. Instead we calibrated the ^{46}Ti(^{3}He,t)^{46}V Q-value against that of the ^{47}Ti(^{3}He,t)^{47}V reaction to the IAS in the T=3/2 multiplet of A=47. This difference is the difference in Coulomb displacement energies (CDE) for isotopes and thus only about 30 keV. To become independent of effects of beam position on the target and on different beam energies and energy losses we measured both reactions simultaneously in one single target. The target was produced by evaporating 20 $\mu g/cm^2$ of a mixture of enriched ^{46}Ti and ^{47}Ti onto a 4 $\mu g/cm^2$ thick carbon backing. The Q3D was positioned at 0° where the L=0 transfer has a maximum.

Fig. 1 shows the relevant part of the spectrum obtained. The measured energy resolution is 5.4 keV (FWHM). The excitation of the IAS of all stable Ti isotopes is visible with intensities consistent with the respective isotopic content of the target. To determine the energy difference between the ^{46}V and ^{47}V peaks we need only the slope of the energy calibration which we obtained from the ^{26}Mg(^{3}He,t)^{26}Al reaction with the same Q3D setting. Thus we obtain a Q-value difference for the (^{3}He,t) reactions on the ^{46}Ti and ^{47}Ti targets of (28.73±0.21) keV. The error consists about equally of the uncertainty in the fitted peak positions and that of the energy calibration. It has to be emphasized that in contrast to the measurement of Ref. [2] no systematic uncertainties like change in beam energy, position of beam or target have to be considered, because of the simultaneous measurement.

The main uncertainty of the reference Q-value for the ^{47}Ti(^{3}He,t)^{47}V reaction in the mass table [5] is the neutron separation energy S_n of ^{47}Ti with 0.29 keV. Therefore we remeasured S_n with the (d,p) reaction at a bombarding energy of 14 MeV. We used an enriched ^{46}Ti target that contains still 28% of ^{48}Ti and observed simultaneously lines at excitation energies around 2.3 MeV in ^{47}Ti and 1.6 MeV ^{49}Ti. Our result $S_n = 8880.58 \pm 0.30$ keV is in good agreement with the tabulated value. Taking the weighted average and from Esch *et al.* [6] both the proton separation energy of ^{47}V and the excitation energy of the IAS we arrive at $Q_{EC}(^{46}\mathrm{V}) = 7052.10 \pm 0.31$ keV. This value is slightly smaller and more precise than the value $Q_{EC}(^{46}\mathrm{V}) = 7052.90 \pm 0.40$ keV from the direct mass measurements [1]. The old reaction Q-value [2] is still off by nearly 3 σ. For the weighted average of all measurements we obtain $Q_{EC}(^{46}\mathrm{V}) = 7052.13 \pm 0.22$ keV and $Q_{EC}(^{46}\mathrm{V}) = 7052.41 \pm 0.24$ keV if we exclude the Vonach *et al.* value. This shows that the latter value has now only little influence on the final result.

As a conclusion we can state that reaction Q-values are indeed competitive with direct mass measurements as long as systematic uncertainties are avoided.

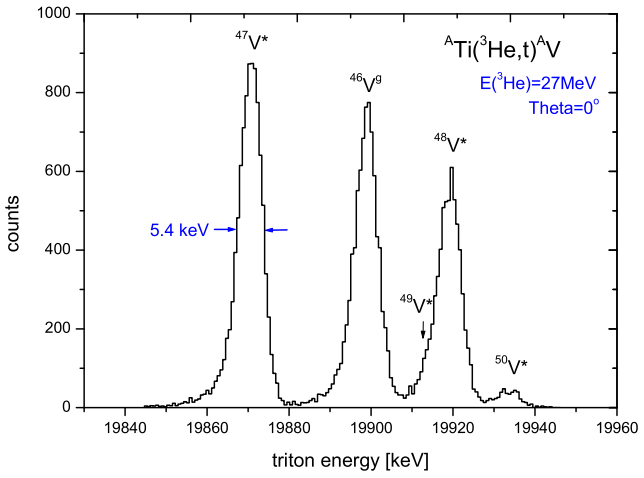

Fig. 1: Part of the (^{3}He,t) spectrum for the mixed ^{46,47}Ti target. All stable isotopes are present in the target as contaminants and for all those the excitation of the IAS can be seen. The energy resolution is 5.4 keV (FWHM).

References

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