EXPERIMENTAL Q-VALUES FAR FROM STABILITY

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As no nuclear masses at present have been determined experimentally far from stability, comparison with calculated mass tables still have to be based on mass-differences found as Q-values in nuclear transformations, of which α, β and delayed proton decay are of interest in this connection.

In recent years a fair amount of α-decay energies have been measured in very neutron deficient regions. As an example, we give in Fig. 1 an already published\(^1\) comparison of α-decay energies of isotopes of mercury and gold with the predictions of two recent and one older mass calculation. There are apparently differences of the order of 1 MeV between the mass tables; the experimental values seem not to prefer any particular formula.

Recently a new source of information has come from studies of delayed proton emitters\(^2,3\). The continuous proton spectra permit determination of \(Q_\beta - B_p\), \(Q_\beta\) being the energy for β-decay to the proton emitting nucleus, and \(B_p\) the proton binding energy. Table 1 is a collection of the information available to us. The material points to the same conclusion as the α-data; all the recent mass formulae predict the energies with an accuracy of the order of 1 MeV, but it is not possible at present to select any particular table. As the symmetry term \((N-Z)\) is changed in this process, it represents a more interesting test on the mass formulae than the α-decay.

α-decay and especially delayed proton decay can yield information on nuclear masses in limited regions only. Until measurements of mass spectrometric nature can be
performed, the establishment of masses far from stability must necessarily be based on systematic studies of Q-values in β-decay. This report deals with some still preliminary on-line studies performed at ISOLDE of positron decay energies for heavy nuclei. Positron emission is almost absent close to stability, but the more neutron deficient nuclei have still reasonably strong positron branches.

Many experimental difficulties, also those due to the short half lives, are dealt with by the application of on-line techniques. Our detectors are shown schematically in Fig. 2. The activity is placed in a slit in a plastic scintillator by means of a tape transport system. The Ge-Li crystal is the second detector in a \( \beta^+ - \gamma \) coincidence set-up. The geometry of the positron detector secures a high efficiency, whereas the room background consisting of \( \gamma \)-rays, which is often noticeable in the experimental hall, is practically eliminated in the coincidence measurements.

Positrons populate with preference low energy levels in the daughter nuclei, and the coincident \( \gamma \)-ray spectra are often much simpler than the total single spectra. In Fig. 3 the coincident \( \gamma \)-ray spectrum of the \(^{184}\text{Au} \rightarrow ^{184}\text{Pt}\) is shown. The only intense lines in addition to the annihilation peak are from the \( 6^+ \rightarrow 4^+ \rightarrow 2^+ \rightarrow 0^+ \) cascade of the ground state rotational band of \(^{184}\text{Pt}\). The intensities indicate that only the \( 6^+ \) and \( 4^+ \) states are strongly excited in the positron decay. These simple \( \gamma \)-ray spectra often provide valuable information on the decay scheme, which is essential also for the correct interpretation of the Q-value measurements.

Our Q-value determinations are based on positron spectra measured in coincidence with a single \( \gamma \)-ray. Due to the good resolution of the Ge-Li detector the background from other \( \gamma \)-rays was sufficiently reduced in the simple coincidence measurements. Selective detection of positron events in the plastic scintillator by
the recording of annihilation radiation in triple or quadruple coincidence arrangements was tried. The advantage with respect to background reduction did not justify the loss in intensity.

Fig. 4 shows the positron spectrum coincident with the $4^+ \rightarrow 2^+$ $\gamma$-transition of $^{184}$Pt. A complete treatment of the data involves corrections for the response function of the plastic detector followed by Fermi analysis. In the figure a simpler procedure, which is often sufficient to establish the maximum energy, is illustrated. The curve represented by the circles is defined on the figure; it gives essentially for each channel the mean energy of all events recorded in higher channel numbers. A transformation like this, which involves only a small computational effort, is useful in connection with spectra containing relatively few counts, as each point is based on integrated information from a larger part of the spectrum.

Fig. 5 illustrates the determination of $Q_\beta$ for the $^{184}$Au $\rightarrow^{184}$Pt decay. Calibration is performed by means of positron spectra of known energy, which have been treated in an identical manner. The low energy parts of the transformed spectra are of less value, as they might be influenced by low energy positron groups, and the highest part suffers from poor statistically accuracy, but a region remains, from which the energy can be extracted with an accuracy of 0.1-0.2 MeV. The $Q_\beta$-value comes out as $5.0^{+0.2}_{-0.2}$ MeV, whereas the mass tables agree upon a value of $\approx 6.3$ MeV.
References


3. P.Hornshøj et al, Delayed - proton Emission from Neutron-deficient Isotopes of Xenon and Mercury. Contribution to this Conference


6. P.A.Seeger and R.C.Perisko, Los Alamos Scientific Laboratory, LA-3751 (1967)

7. W.D.Myers and W.J.Swiatecki, Univ. of Calif., Lawrence Radiation Lab., UCRL-11980 (1965)


Table 1.

Energies of delayed proton groups, \( Q_p - B_p \), in MeV

<table>
<thead>
<tr>
<th></th>
<th>Myers</th>
<th>Seeger</th>
<th>Riddel</th>
<th>Garvey</th>
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<tr>
<td>111Te</td>
<td>+1.07</td>
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<tr>
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<td>+5.1</td>
<td>+0.4</td>
<td>+0.8</td>
<td>+0.8</td>
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</tbody>
</table>

The calculated energies are from ref. 5-9.
Fig. 1 Comparison of experimental $\alpha$-decay energies with the mass tables Refs. 5-7.
Fig. 2 Detector arrangement.
Fig. 3 $\gamma$-ray spectrum of the $^{184}\text{Au} \rightarrow ^{184}\text{Pt}$ decay measured in coincidence with positrons.
Fig. 4  Positron spectrum (x) coincident with the 273 keV $4^+ \rightarrow 2^+$ γ-ray from $^{184}$Pt. The transformation into the curve (o) is defined on the figure.
Fig. 5 Determination of the energy of the positron spectrum Fig. 4.