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TITLE: CALCULATION OF NUCLEAR PROPERTIES FAR FROM THE LINE OF β STABILITY

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Calculation of nuclear properties far from the line of β stability

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For a theoretical study of the decay from the r-process line to the line of β stability many nuclear properties must be known or modelled. From the ground state the nucleus may fission or beta decay. In an excited nucleus there is competition between neutron emission, fission and de-excitation by gamma decay. To compute the various decay rates and corresponding decay paths a decay chain program is required. Fission barrier heights, ground state masses and the corresponding particle separation energies are used as input into this decay chain program. Also required is a knowledge of the beta-strength function. At present we have or are developing sophisticated models, based on the microscopic structure of the nuclei involved, to calculate these quantities.

We have, for instance, calculated nuclear potential-energy surfaces, ground-state masses and shapes by use of a Yukawa-plus-exponential macroscopic model and a folded-Yukawa single-particle potential for 4023 nuclei ranging from ^{16}O to $^{279}112$. These calculations, which extend rather far from stability are discussed in detail in refs.[1-3]. Here we show in fig. 1 calculated and experimental single particle corrections and the than 1 MeV. Particularly noteworthy in fig. 1 is that there seems to be no systematic increase in the deviation between calculated and experimental points as you go far from stability, a desirable feature of a mass formula that is to be used for nuclei out to the r-process line. To give specific numbers for a very neutron-rich nucleus we select ^{99}Rb for which the mass excess -50.60 MeV has recently been measured[4]. The present mass formula[2] gives -51.66 MeV for this nucleus, a 1.06 MeV error, whereas the droplet model predicts this mass excess to be -56.10 MeV[5], a 5.5 MeV error. For further discussions we refer to the publications[1-3] mentioned above.

We will now briefly discuss the model for the β-strength function we are developing by applying it to the rubidium region. The β-strength function for β^- decay of a sequence of rubidium nuclei to strontium nuclei have been studied experimentally by Kratz and collaborators[6]. They find a pronounced change in appearance of the measured β-strength function between ^{95}Rb and ^{97}Rb. For ^{95}Rb and lighter Rb isotopes the spectra show, in the low-energy region, a very distinct peak structure, with the peaks separated by regions of very low strength. For ^{97}Rb the measured strength function has a much smoother appearance.

These strength functions have been studied in a theoretical model[7] that takes deformation into account. In the model calculated Nilsson model wave functions, spherical or deformed, as the case may be, are used as the starting point for determining the wave functions of the mother and daughter nuclei in the β decay. Pairing is treated in the BCS approximation. To account for the retardation of low-energy GT-decay rates, a simple residual interaction specific to GT decay, namely $V_{GT}=\chi:\beta^{1-}\cdot\beta^{1+}:$, is added to the Hamiltonian, as is customarily done. This residual interaction is treated in the RPA approximation. The strength of the interaction is adjusted to get agreement between the calculated and experimental energy of the giant Gamow-Teller resonance for ^{208}Pb and ^{144}Sm. Since the model is based on calculated wave functions and single-particle levels, studies of nuclei far from stability, where little experimental information is available, are more straightforward in this model relative to calculations where "experimental" levels are used. The model can treat deformed nuclei employing wave functions calculated to desired accuracy, within the framework of the model, for the deformed single-particle well.

To give an example of results from such a model and to illustrate the effect of deformation on the calculated β^--strength function we show calculated strength functions for the nucleus ^{97}Rb under the two assumptions of a spherical shape, fig. 2a, or a well-developed deformation, fig. 2b, for the nuclear ground state. The calculation for spherical shape in fig. 2a shows the peak structure so characteristic for the lighter rubidium isotopes, but which is not in agreement with the experimental results for ^{97}Rb. In contrast, the calculation for the deformed case is in excellent agreement with experiment. A more extensive discussion of these results is found in ref.[7].

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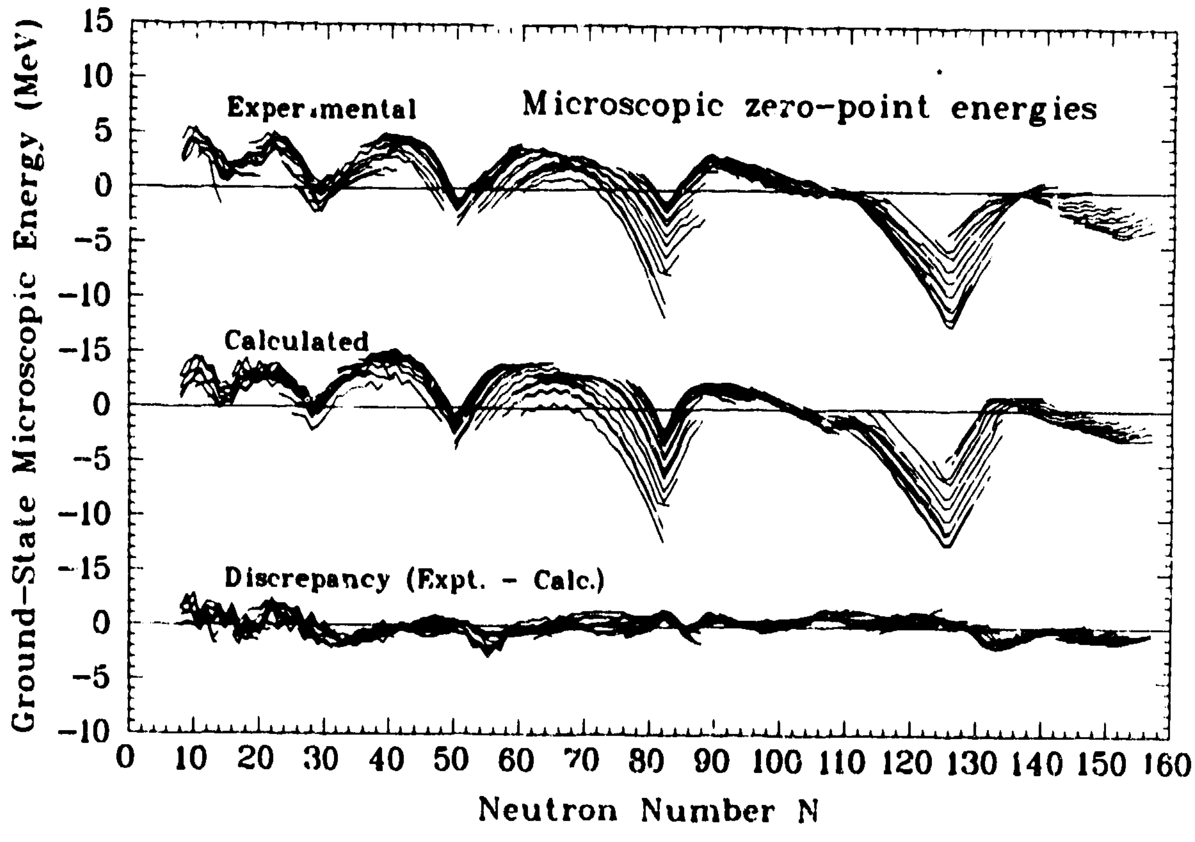


Figure 1

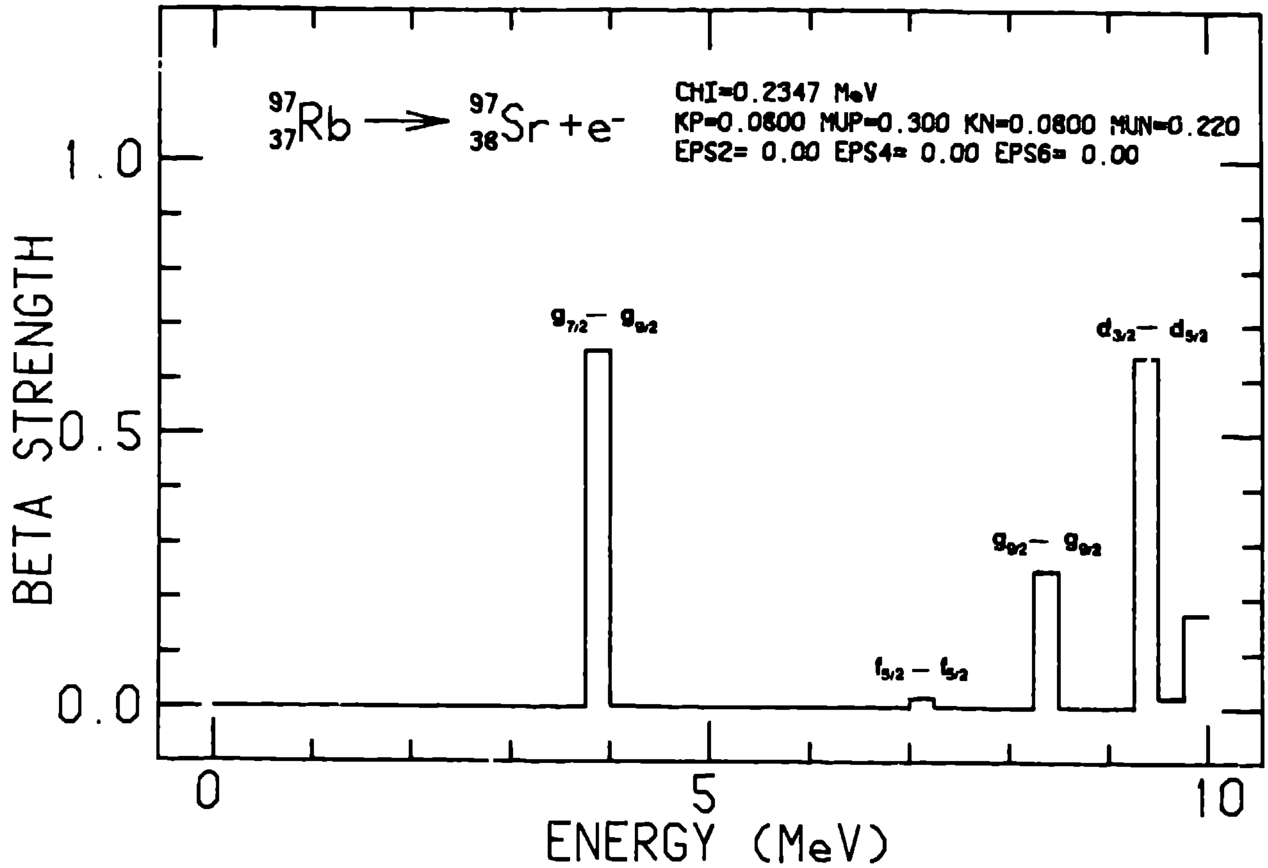
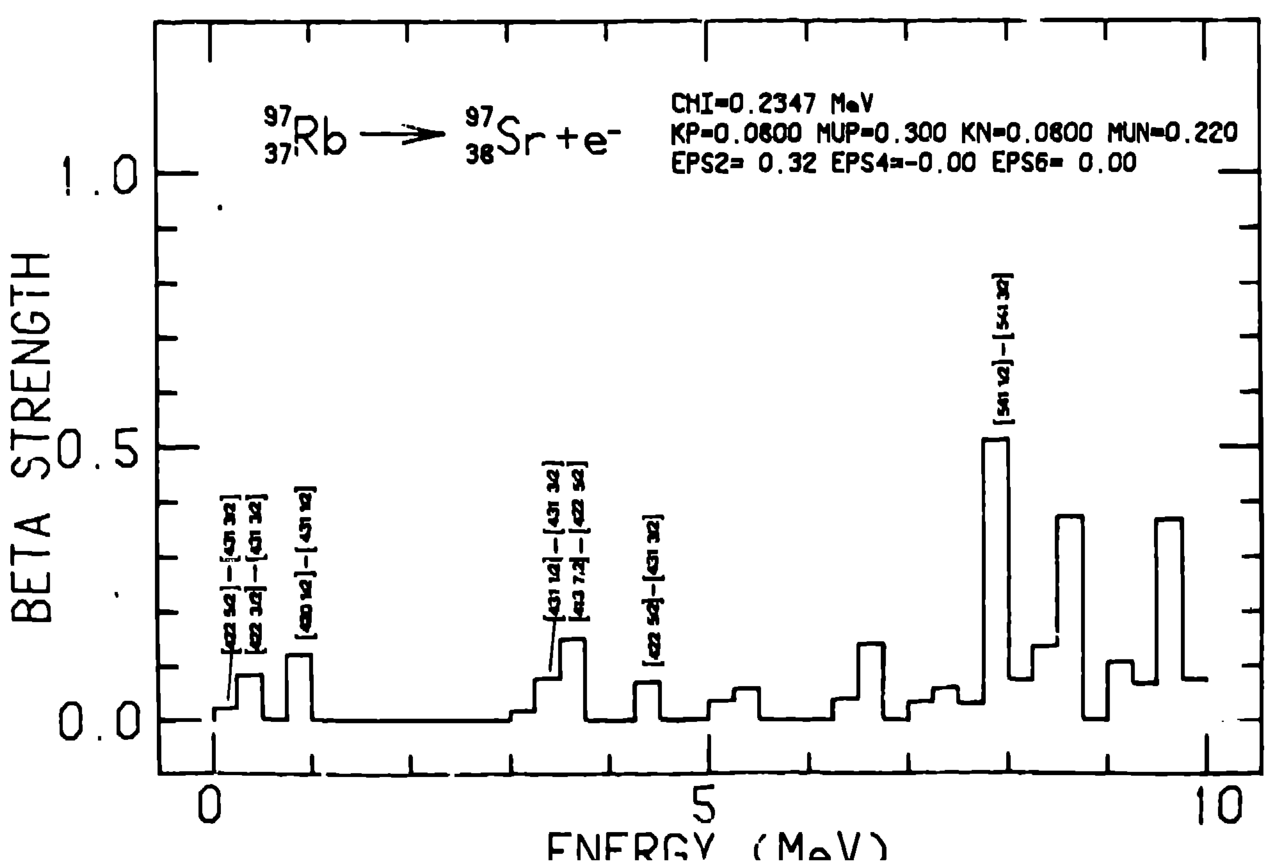

$^{97}_{37}Rb \rightarrow ^{97}_{38}Sr + e^-$
CHI=0.2347 MeV
KP=0.0800 MUP=0.300 KN=0.0800 MUN=0.220
EPS2= 0.00 EPS4= 0.00 EPS6= 0.00
BETA STRENGTH
ENERGY (MeV)
$g_{7/2} - g_{9/2}$
$f_{5/2} - f_{5/2}$
$g_{9/2} - g_{9/2}$
$d_{3/2} - d_{5/2}$

Figure 2a


$^{97}_{37}Rb \rightarrow ^{97}_{38}Sr + e^-$
CHI=0.2347 MeV
KP=0.0800 MUP=0.300 KN=0.0800 MUN=0.220
EPS2= 0.32 EPS4=-0.00 EPS6= 0.00
BETA STRENGTH
ENERGY (MeV)