## LIMITS FROM NEUTRINOLESS $\beta\beta$ DECAY

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Limits on an effective Majorana neutrino mass and a lepton-number violating current admixture can be obtained from lifetime limits on $0\nu\beta\beta$ nuclear decay. The derived quantities are model-dependent, so the half-life measurements are given first. Where possible we list the references for the matrix elements used in the subsequent analysis. Since rates for the more conventional $2\nu\beta\beta$ decay serve to calibrate the theory, results for this process are also given. As an indication of the spread among different ways of evaluating the matrix elements, we show in Fig. 1 some representative examples for the most popular nuclei. For further calculations, see, *e.g.,* Ref. 1

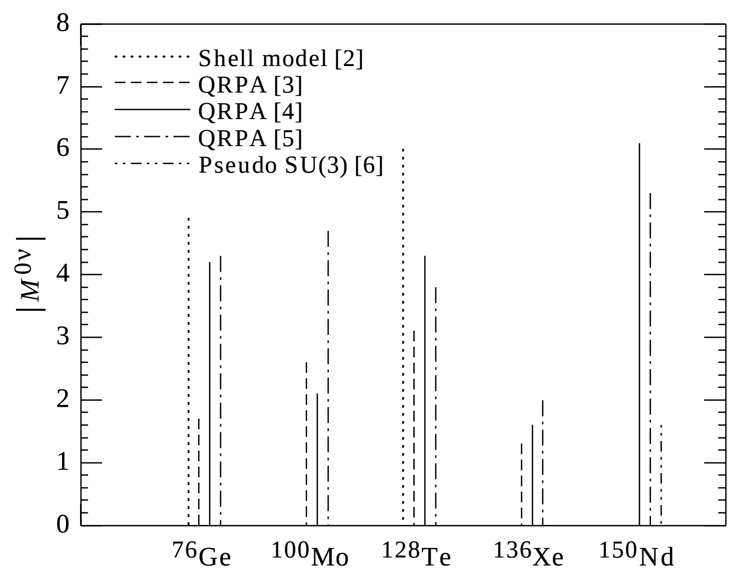


**Figure 1:** Nuclear matrix elements for $0\nu\beta\beta$ decay calculated by a subset of different methods and different authors for the most popular double-beta decay candidate nuclei. Recalculated from the published half-lives using consistent phase-space factors and $g_A = 1.25$. The QRPA [3] value is for $\alpha' = -390$ MeV fm$^3$.

To define the limits on lepton-number violating right-handed current admixtures, we display the relevant part of a phenomenological current-current weak interaction Hamiltonian:

$$H_W = (G_F/\sqrt{2}) \times (J_L \cdot j_L^\dagger + \kappa J_R \cdot j_L^\dagger + \eta J_L \cdot j_R^\dagger + \lambda J_R \cdot j_R^\dagger) + \text{h.c.}$$

where $j_L^\mu = \bar{e}_L \gamma^\mu \nu_{eL}$, $j_R^\mu = \bar{e}_R \gamma^\mu \nu_{eR}$, and $J_L^\mu$ and $J_R^\mu$ are left-handed and right-handed hadronic weak currents. Experiments are not sensitive to $\kappa$, but quote limits on quantities proportional to $\eta$ and $\lambda$.* In analogy to $\langle m_\nu \rangle$ (see Eq. 11 in the "Note on Neutrinos" at the beginning of the Neutrino Particle Listings), the quantities extracted from experiments are $\langle \eta \rangle = \eta \sum U_{1j} V_{1j}$ and $\langle \lambda \rangle = \lambda \sum U_{1j} V_{1j}$, where $V_{ij}$ is a matrix analogous to $U_{ij}$ (see Eq. 2 in the "Note on Neutrinos"), but describing the mixing among right-handed neutrinos. The quantities $\langle \eta \rangle$ and $\langle \lambda \rangle$ therefore vanish for massless or unmixed neutrinos. Also, as in the case of $\langle m_\nu \rangle$, cancellations are possible in $\langle \eta \rangle$ and $\langle \lambda \rangle$. The limits on $\langle \eta \rangle$ are of order $10^{-8}$ while the limits on $\langle \lambda \rangle$ are of order $10^{-6}$. The reader is warned that a number of earlier experiments did not distinguish between $\eta$ and $\lambda$. Because of evolving reporting conventions and matrix element calculations, we have not tabulated the admixture parameters for experiments published earlier than 1989.

See the section on Majoron searches for additional limits set by these experiments.

**Footnotes and References**

* We have previously used a less accepted but more explicit notation in which $\eta_{RL} \equiv \kappa$, $\eta_{LR} \equiv \eta$, and $\eta_{RR} \equiv \lambda$.


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