The vector $\boldsymbol{\xi}$ can be considered as the operator of the isotopic spin of the lepton. Thus the lepton is a particle with isotopic spin 1. Its three charge states (electron, positron, and neutrino) correspond to the three possible eigenvalues ($\mp 1, 0$) of ξ_3. The three wave functions u, v, w (each of which is a four-component Majorana spinor) themselves form a vector in the space of the isotopic spin.

As is well known,[2] there exists also an irreducible representation of rank four of the three abstract operators satisfying (4). This is given by the Hermitian matrices

$$\xi_1'=\begin{pmatrix} 0 & 0 & 0 & i \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -i & 0 & 0 & 0 \end{pmatrix}, \quad \xi_2'=\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & i \\ 0 & 0 & 0 & 0 \\ 0 & -i & 0 & 0 \end{pmatrix}, \quad \xi_3'=\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & i \\ 0 & 0 & -i & 0 \end{pmatrix}. \tag{6}$$

If we write $\lambda_3=-i(\xi_2'\xi_1'-\xi_1'\xi_2')$, etc., the matrices λ_j are just reduced in the form

$$\lambda_1=\begin{pmatrix} \xi_1 & 0 \\ 0 & 0 \end{pmatrix}, \quad \lambda_2=\begin{pmatrix} -\xi_2 & 0 \\ 0 & 0 \end{pmatrix}, \quad \lambda_3=\begin{pmatrix} \xi_3 & 0 \\ 0 & 0 \end{pmatrix} \tag{7}$$

and satisfy the relations $\lambda_2\lambda_1-\lambda_1\lambda_2=-i\lambda_3$, etc. Thus these λ-matrices can be interpreted as components of the isotopic spin of a particle belonging to (6). This isotopic spin has two values 0 and 1. The particle has four charge states, two charged ones and two different neutral ones. Its wave function φ' has four components (u', v', w', f'), each of which can be, e.g., a Majorana spinor. The first three wave functions u', v', w' form a vector, whereas f' is a scalar (in the isotopic spin-space). The charge density is given by $\rho'=e\varphi'^{\dagger}\lambda_3\varphi'$. Different interactions with nucleons can be defined by writing φ' instead of φ and $\boldsymbol{\lambda}$ or $\boldsymbol{\xi}'$ instead of $\boldsymbol{\xi}$ in (1).[3]

[1] J. R. Oppenheimer and J. S. Schwinger, Phys. Rev. **56**, 1066 (1939). These authors pointed out that the emission of an electron-positron pair from the nucleus O^{16*} could be explained by introducing such a direct (nonelectromagnetic) interaction of protons and/or neutrons with the quantized electron-positron wave field. But they abandoned this possibility in favor of a less radical alternative, which explains the pair as being ejected through the electromagnetic influence of nuclear multipole moments. Recent experiments [Phillips, Cowie, and Heydenburg, Phys. Rev. **83**, 1049 (1951)] show, however, that also the nucleus Be^{8*} can emit a pair, although this nucleus would not be expected to have a similar structure (even parity) to that assumed for O^{16*}. Thus the (electromagnetic) mechanism adopted by Oppenheimer and Schwinger may be actually inoperative, and it is perhaps worth while to consider once again the first possibility.

[2] N. Kemmer, Proc. Cambridge Phil. Soc. **39**, 189 (1943).

[3] The π-mesons ($\pi^{\pm}$, π^0) can also be considered as the three charge states of a particle with isotopic spin 1 (represented by ξ). Various mass-operators, commutative with the charge-operator ξ_3, can be constructed.

Lifetime of an Excited State of $_{66}Dy^{160}$ and Upper Limits for Some Other Nuclei

F. K. McGowan
Oak Ridge National Laboratory, Oak Ridge, Tennessee
(Received November 16, 1951)

An excited state in $_{66}Dy^{160}$ with a half-life of $(1.8\pm 0.2)\times 10^{-9}$ sec has been observed with a delayed coincidence scintillation spectrometer using sources of Tb^{160}. The β-decay of Tb^{160} is known to consist of at least two components and is accompanied by a large number of gamma-rays and conversion electrons.[1,2]

The delayed coincidence scintillation spectrometer is similar to that described previously.[3] In many cases the lifetimes of excited nuclear states are too short to be measured and only upper limits can be set.

In the case of Dy^{160}, delayed coincidences were observed by exciting one channel of the delayed coincidence apparatus with 165 to 250 kev nuclear β-rays and the other channel by the L, M, or N internal conversion electrons of the 85-kev transition. The spectrum of the radiation announcing the formation of the metastable state appears to be a β-ray distribution with a maximum energy of about 900 kev and presumably corresponds to the 860 kev β-ray observed in the decay of Tb^{160} from magnetic spectrometer measurements.[1] The L and M internal conversion electrons corresponding to an 85-kev transition were observed in the spectrum of the delayed radiation. No other gamma-rays of higher energy appear in the spectrum of the delayed radiation.

Under favorable conditions a half-life of 5×10^{-10} sec can be detected with the apparatus using anthracene detectors. The observed upper limits of the half-life of some other excited states are listed in Table I.

TABLE I. Upper limits of the half-life of some excited nuclear states.

Nucleus	E_γ	$T_{1/2}$	Radioactive source
$_{52}Te^{123}$	159 kev	$<1.0\times 10^{-9}$ sec	Te^{123*}
$_{52}Te^{125}$	35	$<2.0\times 10^{-9}$ sec	Te^{125*}
$_{67}Ho^{165}$	95	$<0.8\times 10^{-9}$ sec	Dy^{165}
$_{80}Hg^{198}$	411	$<0.4\times 10^{-9}$ sec	Au^{198}
$_{81}Tl^{203}$	280	$<0.4\times 10^{-9}$ sec	Hg^{203}

[1] Burson, Blair, and Saxon, Phys. Rev. **77**, 403 (1950).

[2] Cork, Branyan, Rutledge, Stoddard, and LeBlanc, Phys. Rev. **78**, 304 (1950).

[3] F. K. McGowan, Phys. Rev. **80**, 923 (1950).

Nuclear Reaction Energies*

D. M. Van Patter, A. Sperduto, P. M. Endt, W. W. Buechner, and H. A. Enge
Physics Department and Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge 39, Massachusetts
(Received November 13, 1951)

In a previous publication,[1] the measurements of thirty-eight reaction energies were reported. Since then, the ground-state Q-values of ten additional nuclear reactions have been measured using the 180-degree magnetic spectrograph at MIT. The results are listed in Table I, together with four of the published Q-values that have been revised in the light of new data. Comparison is made with the most recent results of other workers. It may be noted that the reaction energies for the $Mg^{25}(d, p)Mg^{26}$ and $Si^{29}(d, \alpha)Al^{27}$ reactions have not been previously reported by other workers. In the case of the $Si^{29}(d, p)Si^{30}$ and $P^{31}(d, p)P^{32}$ reactions, the reference value is obtained by subtracting a deuteron binding energy of 2.23 Mev from the (n, γ) measurements of Kinsey and his co-workers.[2]

TABLE I. Observed reaction energies.

Reaction	Present Q-value (Mev)	Other Q-value (Mev)
$Ne^{20}(d, p)Ne^{21}$	4.529 ± 0.007	$4.54\ \pm 0.04$[a]
$Ne^{22}(d, p)Ne^{23}$	2.964 ± 0.007	2.96[b]
$Na^{23}(p, \alpha)Ne^{20}$	2.372 ± 0.008	$2.34\ \pm 0.04$[c]
$Mg^{25}(d, \alpha)Na^{23}$	7.019 ± 0.013	7.2[d]
$Mg^{25}(d, p)Mg^{26}$	8.880 ± 0.012	
$Mg^{26}(d, p)Mg^{27}$	4.207 ± 0.006	$4.21\ \pm 0.10$[e]
$Al^{27}(p, \alpha)Mg^{24}$	1.595 ± 0.007	1.585 ± 0.015[c]
$Si^{29}(d, \alpha)Al^{27}$	5.994 ± 0.011	
$Si^{29}(d, p)Si^{30}$	8.388 ± 0.013	$8.32\ \pm 0.05$[f]
$P^{31}(p, \alpha)Si^{28}$	1.909 ± 0.010	$1.85\ \pm 0.02$[g]
	Revised Q-values	
$Mg^{24}(d, p)Mg^{25}$	5.097 ± 0.007	$5.03\ \pm 0.05$[h]
$Si^{30}(d, p)Si^{31}$	4.364 ± 0.007	$4.33\ \pm 0.05$[i]
$P^{31}(d, \alpha)Si^{29}$	8.158 ± 0.011	
$P^{31}(d, p)P^{32}$	5.704 ± 0.008	$5.71\ \pm 0.03$[f]

[a] R. Middleton and C. T. Tai, Proc. Roy. Soc. (London) **A64**, 801 (1951).
[b] J. Ambrosen and K. M. Bisgaard, Nature **165**, 888 (1950).
[c] J. M. Freeman, Proc. Roy. Soc. (London) **A63**, 668 (1950).
[d] M. S. Livingston and H. A. Bethe, Revs. Modern Phys. **9**, 245 (1937).
[e] Allan, Wilkinson, Burcham, and Curling, Nature **163**, 210 (1949).
[f] See reference 2.
[g] See reference 3.
[h] H. R. Allan and C. A. Wilkinson, Proc. Roy. Soc. (London) **A194**, 131 (1948).
[i] H. T. Motz and R. F. Humphreys, Phys. Rev. **80**, 595 (1950).