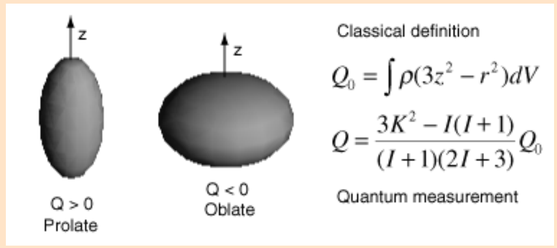
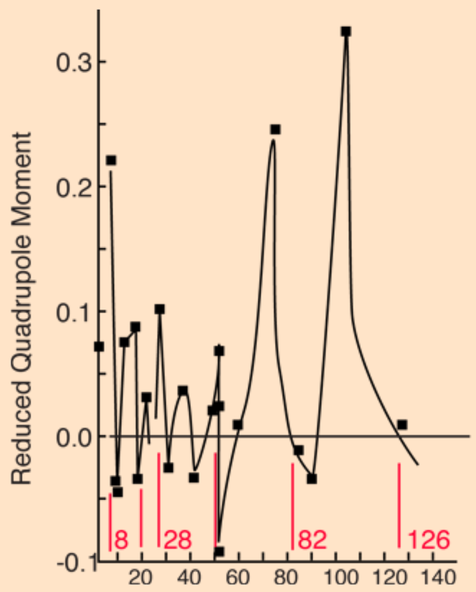
Electric Quadrupole Moments of Nuclei

The nuclear electric quadrupole moment is a parameter which describes the effective shape of the ellipsoid of nuclear charge distribution. A non-zero quadrupole moment Q indicates that the charge distribution is not spherically symmetric. By convention, the value of Q is taken to be positive if the ellipsoid is prolate and negative if it is oblate.



The quantity Q_0 is the classical form of the calculation represents the departure from spherical symmetry in the rest frame of the nucleus. The expression for Q is the quantum mechanical form which takes takes into account the nuclear spin I and the projection K in the z-direction.

One of the expectations of the shell model for the nucleus is that for closed shells the nuclear charge is spherically symmetric. If a nucleus is not spherically symmetric, it will have a non-zero electric quadrupole moment, so the measurement of the quadrupole moment is a test of the shell theory. Since the quadupole moment depends upon the size and charge of the nucleus, a better comparison is obtained by normalizing for those factors, giving what is called a "reduced quadrupole moment". A plot of measured values shows that magic numbers of neutrons or protons correlate with near-zero quadrupole moments.



Quadrupole measurements for odd-A nuclei. The horizontal axis is either neutron number or proton number, whichever is odd.

For a shell model, those nuclei with closed shells should be spherically symmetric and have no quadrupole moment.

After Booth & Combley

Electric quadrupole moments of nuclei can be measured brom hyperfine splitting of atomic spectral lines, from quadrupole hyperfine splitting of molecular rotational spectra, and other spectroscopic techniques.

Nuclide	Q (eb)
^{2}H (D)	+0.00288
^{17}O	-0.02578
^{59}Co	+0.40
^{63}Cu	-0.209
^{133}Cs	-0.003
^{161}Dy	+2.4
^{176}Lu	+8.0
^{209}Bi	-0.37

The electric quadrupole moment has the units of Coulomb x meter^2. It is sometimes tabulated in units of e x 10^{-24} cm^2 where e is the electron charge. In nuclear cross-section measurements, the quantity 10^{-24} cm^2 is called a "barn" and is represented by b. So sometimes the quadrupole unit is written "eb" for electron-barns. Usually the quadrupole moments will be a few tenths in these units until you reach mass numbers around 150. Then quadrupole moments around 2 are common and have been measured as high as 8.

Data from V. S. Shirley, Table of Isotopes, Wiley, New York, 1978, Appendix VII.

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