tion of the dipole axis (*9*), λ_N is 200° in terms of system III (1965.0). If our assumptions are correct, the pole will remain at this longitude indefinitely, whereas it will drift slowly in terms of the older system III (1957.0). The accepted value of β is 10°. We now postulate that, to a first approximation, decametric radiation escaping from Jupiter is beamed parallel to a cone of radius vectors having constant magnetic latitude, Φ_0. The radiation will reach the earth whenever Φ_E is equal to Φ_0. The central meridian longitudes at which this occurs are given by

$$\lambda^\circ = 200^\circ + \arccos\left[\frac{\Phi_0 - D_E}{10}\right]$$

If the radiation escaping the northern hemisphere is beamed at magnetic latitude Φ_0, that from the southern hemisphere should be beamed at $-\Phi_0$. The simple model thus predicts for a given value of D_E four values of λ at which radiation should reach the earth. Figure 3 shows, as a function of date, the values of λ_{III} (1965.0) for the centers of sources A and C, and also two curves representing solutions of the above equation for λ for a particular pair of values $\pm\Phi_0$. The source C points were obtained from Hayward's analysis of University of Florida data (*10*). The best fit to the observed points was obtained with $\Phi_0 = \pm 6.04°$. The fit is remarkably good. The fact that sources A and C lie on opposite sides of the magnetic equator is in agreement with the results of polarization measurements (*11*). It was expected that the third and fourth solutions of the above equation for λ for the same $|\Phi_0|$ would have fit the source B_1 and B_2 points, but this was not the case; these curves and points were not included in Fig. 3.

The results seem to indicate that while the field at longitudes near sources A and C is approximately that of a dipole, it is greatly distorted in the source B region. The positions of sources B_1 and B_2 could perhaps be accounted for if the shape of the field in this region were known. In further support of this idea, we again call attention to the results of Roberts and Komersaroff (*9*) at decimetric wavelengths. They concluded that departures from a dipole field are most pronounced at the early system III (1957.0) longitudes, that is, in the decametric source B region.

The evidence thus appears strong that in the vicinity of 18 Mc/s the source A radiation from Jupiter is beamed into a thin curved sheet which is inclined 6° north of the same magnetic equator deduced from decimetric observations. Although the rotation period of the magnetic field probably remains constant, the apparent source A period differs from it by a small amount which depends on the rate of change of the Jovicentric declination of the earth. The observed width of source A indicates that the thickness of the beam is about 10°. The magnetic latitude corresponding to the beam center is probably a function of frequency; observations by Hayward at the University of Florida (*8*) have indeed indicated that the apparent rotation period of source A depends somewhat upon frequency. It should be possible to account quantitatively for the long-term variation in occurrence probability and source width on the basis of beaming. As D_E approaches its most negative value, less of the source A beam can reach the earth, and as a result, both occurrence probability and source width approach minimum values.

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25 April 1966

Atomic Nuclei: Moments of Inertia and Quadrupole Moments

Abstract. *Moments of inertia and quadrupole moments of deformed even-even nuclei were calculated in the closely packed spheron model.*

In Pauling's extremely simplified classic and static spheron model of atomic nuclei (*1*), nuclei are considered as aggregates of closely packed, rigid clusters. In spite of its simplicity the model reproduces well the magic numbers, the proton : neutron ratio, the onset of spheroidal deformation, and such. Of interest is calculation from this model of other static properties of nuclei, such as moments of inertia and quadrupole moments.

The moment of inertia γ and the quadrupole moment Q of a given nucleus may be calculated by use of one of the microscopic theories (*2*). Crude approximations are obtained with phenomenological models: the rigid-body model (which gives the same results as the cranking model) and the liquid-drop model.

I consider the nucleus as an aggregate of spherons. In calculating the moment of inertia I assume that the moment of inertia of a spheron around an axis through its center-of-mass is zero, as it should be in quantum mechanics for spherical objects (*3*). The origin of the coordinate system is put in the center-of-mass of the nucleus, which is axially symmetrical around the axis z. The moment of inertia around the axis y is

$$\gamma = \Sigma\, m_i(x_i^2 + z_i^2) \qquad (1)$$

where x_i, y_i, and z_i are the coordinates of the center-of-mass and m_i is the nucleon number of the ith spheron. The sum runs over all spherons in the nucleus.

I consider that rare-earth nuclei have two spherons in the inner core; this holds best for maximally deformed nuclei—those away from closed shells. Two of the 17 spherons of the outer core are arranged in a straight line with the spherons of the inner core. The remaining 15 spherons form three rings of five spherons in the interstices between the two spherons in the line. The spherons of the mantle form rings with, maximally, nine spherons in the interstices of two rings of the outer core, and form caps with six or three spherons at the poles.

For a given nucleus, the α-particles,

tritons, and dineutrons are at first distributed in accordance with the level scheme over the three layers; later the Coulomb repulsion is taken into account, and the α-particles are forced into outer layers and into the caps. Various configurations of spherons are considered to vary the distribution of α-particles over the layers and, to some extent, the geometrical arrangement of the spherons in the mantle.

The moments of inertia are calculated for various configurations. The experimental value of γ for a given nucleus should lie between the minimum and the maximum calculated value; the calculated values are in general too large, though for some configurations the minimum value comes close to the experimental ones.

However, the calculated quadrupole moments for these configurations are much too small, so one should not discuss only moments of inertia but quadrupole moments also. Intrinsic quadrupole moments are calculated with the aid of

$$Q = \Sigma e_i(3z_i^2 - x_i^2 - y_i^2 - z_i^2) = \Sigma e_i(2z_i^2 - r_i^2) \quad (2)$$

where e_i is the number of protons in the ith spheron and r_i^2 denotes $x_i^2 + y_i^2$. For spherical nuclei, Eq. 2 gives $Q = 0$, while Eq. 1 does not give $J = 0$ as it should. Thus quadrupole moments are more reliable than moments of inertia in classic approximations.

Now I calculate quadrupole moments for various configurations, and configurations leading to much-too-small Q are discarded; the experimental value of Q should lie between the maximum and minimum calculated values.

The results, together with experimental points (Fig. 1), show overall agreement for quadrupole moments—all one can expect for such a simple model. The fact that the values of corresponding moments of inertia are too high is not surprising for a classic approximation, yet it seems that the deviations are somewhat smaller than for the rigid-body model. Results are similar for mass numbers in the region around 230, for nuclei with three spherons in the inner core.

The nucleus is axially symmetrical, so by making

$$\Sigma x_i^2 = \Sigma y_i^2 = \tfrac{1}{2}\Sigma r_i^2$$

one gets the following approximate formulas:

$$\Sigma z_i^2 = \tfrac{1}{2}\gamma/\bar{m} + \tfrac{1}{2}Q/\bar{e}); \quad \Sigma x_i^2 = \tfrac{1}{2}(\gamma/\bar{m} - \tfrac{1}{2}Q/\bar{e})$$
$$z^2 = \tfrac{1}{2}(\gamma/A + \tfrac{1}{2}Q/Z); \quad x^2 = \tfrac{1}{2}(\gamma/A - \tfrac{1}{2}Q/Z)$$

$\bar{m} = 2A/N$ is the average nucleon number and $\bar{e} = 2Z/N$ is the average proton number in a spheron. The ratio $(\overline{x^2}/\overline{z^2})^{1/2}$ (or better the ratio of

$$b = (5\overline{x^2})^{\frac{1}{2}} + 1.5 \text{ fm}$$

and

$$a = (5\overline{z^2})^{\frac{1}{2}} + 1.5 \text{ fm}$$

where 1.5 fm is an average spheron radius) may measure nuclear deformation. The value

$$\delta = \tfrac{1}{2}(1 - b^2/a^2) \approx 0.3$$

for nuclei considered here agrees to within 10 percent with values for δ otherwise obtained.

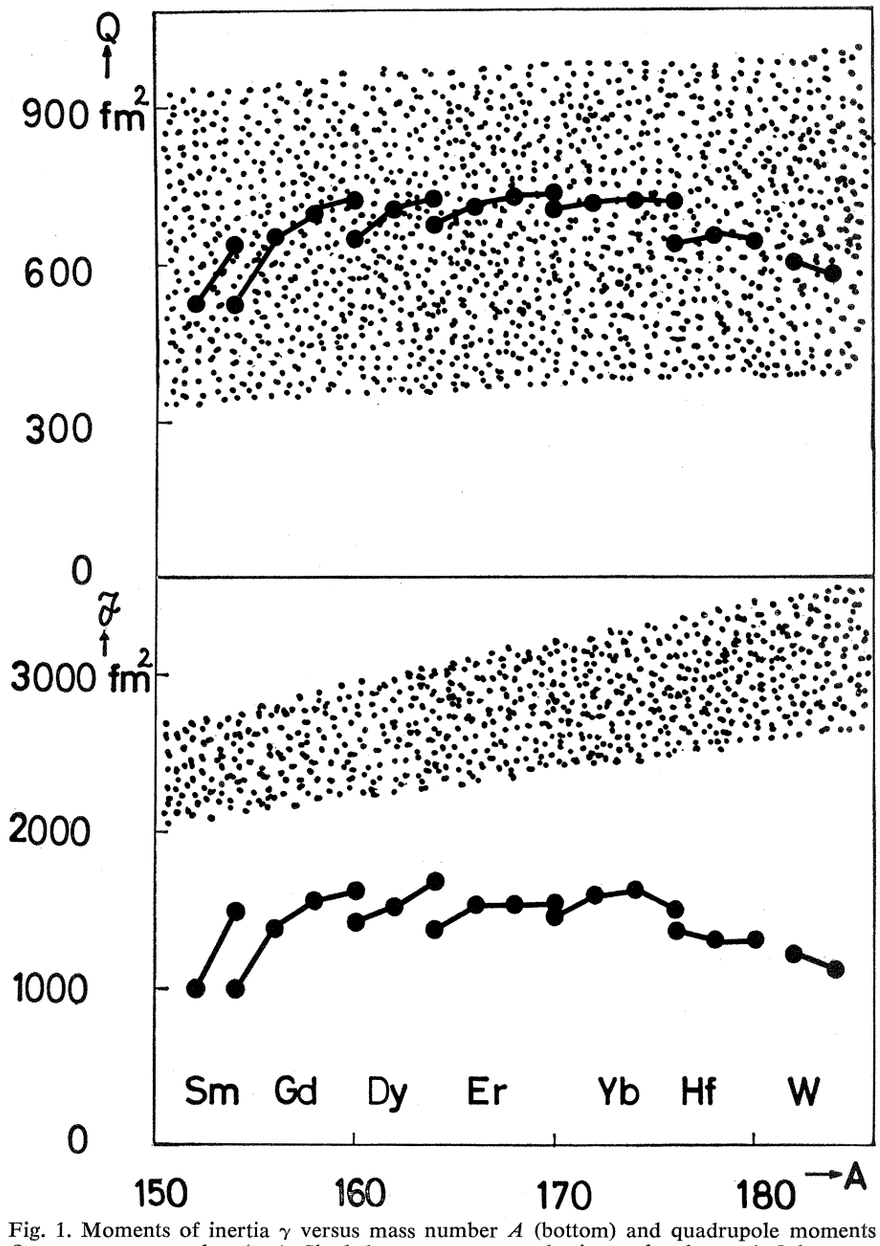

Fig. 1. Moments of inertia γ versus mass number A (bottom) and quadrupole moments Q versus mass number (top). Shaded areas represent the intervals of γ and Q between the minimum and the maximum values in the spheron model. The packing radii 1.62 fm, 1.47 fm, and 1.28 fm were taken for the α-particle, the triton, and the dineutron spheron, respectively. Experimental values are from (*4*, *5*). For microscopic theories with minimum number of adjustable parameters, agreement between experiment and theory is not quite satisfactory (*5*, *6*).

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Photosensitizing Compounds in Extracts of Drinking Water

Abstract. *By means of a photodynamic bioassay, with* Paramecium caudatum, *photosensitizing compounds have been demonstrated in extracts of finished drinking water in the United States. These findings are of interest in view of a demonstrated association between photodynamic toxicity and carcinogenicity. Neither the origin nor the identity of these compounds has been determined.*

Using a series of defined polycyclic compounds, we have demonstrated a significant positive association between photodynamic toxicity to *Paramecium caudatum* and carcinogenicity (*1*). From such data, a photodynamic bioassay was developed for purposes of large-scale screening, as a rapid and sensitive presumptive index, for carcinogenicity attributable to polycyclic compounds (*2*). The assay has been applied to organic extracts and fractions of particulate atmospheric pollutants from numerous urban and nonurban sources in the United States (*3*). We now report significant concentrations of photosensitizing compounds, as judged by the photodynamic bioassay, in extracts of finished drinking water.

Extracts from finished drinking water are routinely collected by the Water Supply Section of the Division of Environmental Engineering of the U.S. Public Health Service for the identification and measurement of organic chemicals. For this purpose, large volumes of water are filtered through columns of activated carbon, at a flow rate of 0.25 gallon (0.94 liter) per minute by standardized procedures (*4*). The carbon filters are subsequently extracted with chloroform and then with 95 percent ethanol. Such extracts, collected in 1961 from finished drinking water of four cities with predominantly nonindustrial watersheds in the northeastern United States, were used in our studies (Table 1). With the exception of city D, the concentrations of these chloroform extracts are less than the recommended Public Health Service standard of 200 μg/liter (*5*).

Fine aqueous suspensions of solvent-free water extracts, freshly prepared over a range of 1000 to 1.56 μg/ml, were incubated with suspensions of *P. caudatum* in the log-phase of growth, and then irradiated with long-wave ultraviolet light from a high-pressure mercury vapor tube with a peak at 360 mμ (*2*). The endpoints of photosensitizing effects were the times required for immobilization of 90 percent of the motile cells (LT_{90}), as determined with a stereoscopic microscope through which all wells were scanned, with an arbitrary observational limit of 1.5 hours. Mean LT_{90} values (Table 2) were determined from a minimum of three independent pairs of replicate assays, and dose-response curves were prepared for each set of extracts. As a standard, benzo-[*a*]pyrene (BP) was simultaneously assayed at tenfold dilutions from 1.0 to 0.001 μg/ml; this compound is a convenient standard in such nondilution types of photodynamic assays, and the results may properly be expressed with reference to the standard without implying the obligate presence of BP in the test materials assayed. A composite dose-response curve based on eight paired replicate assays of BP is presented in Fig. 1, together with dose-response curves for water extracts of city A. These extracts have steep, approximately parallel dose-response curves, and a similar relation obtains for the extracts from the other three cities.

The photodynamic activities of the BP standard and each pair of extracts were determined by interpolation of the respective concentrations (C_{30}) yielding LT_{90} values of 30 minutes (Fig. 1). Relative photodynamic potencies were determined from the C_{30} values and computed both on a weight basis, as microgram equivalents of BP per gram of extract, and on a volume basis, as micrograms of BP equivalents per gallon of water (Table 3). On a weight basis the potency of the chloroform extracts exceeds that of the corresponding alcohol extracts, although these potencies span only a tenfold range. With the exception of the sample from city A, which has a disproportionately low concentration of

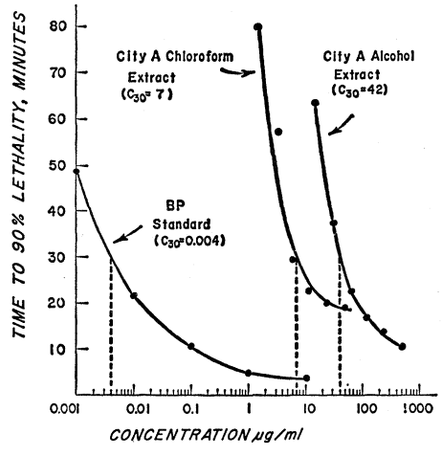

Fig. 1. Photodynamic assay results and method of interpolation for concentrations (C_{30}) producing 90-percent lethality (LT_{90}) within 30 minutes.

Table 1. Sources and yields of water extracts. CE, chloroform extract; AE, alcohol extract. (The same abbreviations are used in Tables 2 and 3.)

City	Type of water	Volume of water filtered (gal)	Weight of extracts (g)		Extract yield (μg/gal)	
			CE	AE	CE*	AE
A	Surface	5040	0.223	1.776	44	352
B	Surface and springs	5000	1.984	3.096	397	619
C	Surface	2400	1.481	2.207	617	920
D	Surface	5205	4.331	2.282	832	438

* Corresponding values for cities A, B, C, and D are 11.6, 104.9, 163.0, and 219.8 respectively.