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The Photoneutron Cross Section of Natural Osmium

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Abstract

The absolute (γ, xn) cross section of natural osmium is extracted from bremsstrahlung yield curves measured from the lowest (γ, n) threshold of osmium isotopes up to 28 MeV in energy steps of 0·2 MeV. The VBPL method of Bramanis *et al.* (1972) has been used to unfold the cross section from bremsstrahlung yield data. The results do not show evidence of significant amounts of splitting of the giant dipole resonance, as might be expected from the theoretical predictions of Sedlmayr *et al.* (1974), but at the same time are not inconsistent with their general features.

The transitional nuclei are of current interest both in experimental and theoretical studies since, for example, the neodymium isotopes are known to constitute a transition region from the spherical nucleus ^{142}Nd through to the prolate deformed nucleus ^{150}Nd. Another transition region exists in the tungsten–osmium–platinum range where the nuclear shape changes from a large prolate deformation to an oblate deformation. While ^{184}Os has a prolate deformation, oblateness is predicted to commence with the ^{192}Pt isotope for which the quadrupole moment of the first excited 2^+ state changes from negative to positive between ^{192}Os and ^{192}Pt (Kumar and Baranger 1968). Osmium is the only case known to exist where a nuclear phase transition from prolate-deformed to γ-unstable is predicted for its isotopes.

A comprehensive theory that can treat vibrational, rotational and transitional characteristics on an equal level has been proposed by Rezwani *et al.* (1970), Gneuss and Greiner (1971) and Sedlmayr *et al.* (1974). The criterion of this model is that the collective potential energy surface (CPES) of a given nucleus is constructed usually from the experimentally known low-lying energy spectrum and transition probabilities. Once the CPES is obtained, the ground state collective wavefunction and the zero-point energy, which in turn is related to the potential energy at minimum, are calculated. However, this treatment is strictly valid only if all the collective degrees of freedom are considered at the same time (Maruhn and Greiner 1973). In addition, the photoabsorption cross section can be calculated by incorporating the CPES into the dynamic collective model which predicts the degree of splitting of the main giant dipole resonance (GDR).

Sedlmayr *et al.* (1974) calculated the photoabsorption cross sections of osmium isotopes using the above model. They predicted a transitional change from a double-peaked structure in ^{184}Os to a possibly tri-peaked structure in ^{190}Os and ^{192}Os. The motivation of the present experiment was to test this theoretical prediction.

The measurement was made on natural osmium consisting of the most abundant isotopes ^{190}Os and ^{192}Os which make up 67% of the total. Unfortunately, this precluded a fully quantitative comparison with the theory.

No other measurements on natural osmium are yet available for comparison with the present measurement. Nevertheless, (γ, xn) cross section measurements on ^{190}Os (Goryachev *et al.* 1973) and on ^{188}Os–^{192}Os (Berman *et al.* 1976) have been made.

Experimental Details

The target consisted of 20 g of natural osmium enclosed in a plastic cylinder with thin Mylar windows. An inert argon atmosphere was introduced into the cylinder to prevent any oxidation of the osmium. The (γ, n) yield curves were measured using the technique described elsewhere (Hughes *et al.* 1975). The γ-ray dose was monitored by a thin transmission chamber which was calibrated against the standard NBS P2 chamber (Pruitt and Domen 1962) to obtain the absolute photon flux.

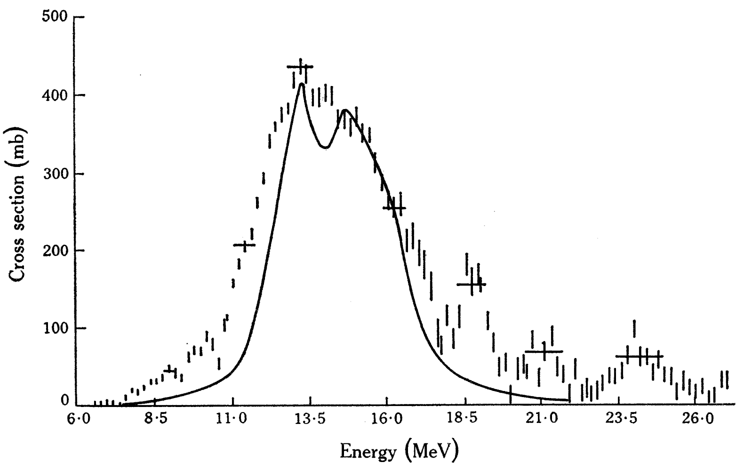

Fig. 1. Comparison of the absolute (γ, xn) cross section of natural osmium from the present measurements with the curve resulting from the theoretical predictions of Sedlmayr *et al.* (1974), after suitable weighting for isotopic abundances. The vertical bars representing the experimental results are each equal in length to two standard deviations obtained from the statistical errors on the yield points; the occasional horizontal bars give the energy resolution of neighbouring cross section points emerging from the VBPL analysis.

The energy calibration of the 35 MeV betatron was based on the thresholds of ^{209}Bi(γ, n), 7·43 MeV; ^{75}As(γ, n), 10·24 MeV; ^{16}O$(\gamma, 2n)$, 28·89 MeV; and the 17·27 MeV break in the ^{16}O(γ, n) yield. The linearity and the stability of the betatron energy were checked by measuring the break in the ^{16}O(γ, n) yield at $21 \cdot 7 \pm 0 \cdot 1$ MeV, which is easy to detect. Correction for the neutron multiplicity effect was made using the usual statistical model approach as described by Hicks and Spicer (1973). The fraction x of directly emitted neutrons was taken as 0·35, following Bergere *et al.* (1968), and the level density coefficient a as $\frac{1}{10}A$ (MeV^{-1}) for all osmium isotopes present in the target. The final absolute (γ, xn) cross section of natural osmium was obtained using the Variable Bin Penfold Leiss (VBPL) analysis method of Bramanis *et al.* (1972).

Results and Conclusions

The absolute (γ, xn) cross section of natural osmium deduced from the present measurements is shown in Fig. 1. Also presented there for comparison are the theoretical predictions of Sedlmayr *et al.* (1974), which were calculated for isotopes A = 184, 186, 188, 190 and 192 and then combined after suitable weighting for the corresponding isotopic abundances. In arriving at their composite curve, Sedlmayr *et al.* used an arbitrary spreading width of 1·5 MeV for each component dipole transition. Even though there is some smoothing out of structure resulting from the different isotopic behaviour here, a distinct dip between 13·3 and 14·8 MeV is predicted. There does not appear to be any support from experiment for this dip even though the effective resolution of the cross section analysis (0·7 MeV here) is adequate for the purpose of this comparison. The present results are consistent with the measurements of Goryachev *et al.* (1973) on ^{190}Os.

The high energy structure in the cross section which is evident in Fig. 1 beyond 18 MeV may be an indication of quadrupole excitations. Such excitations in this region have been predicted by Ligensa *et al.* (1966) and have been measured for ^{181}Ta in this laboratory by Hicks and Spicer (1973) using the same techniques as in the present experiment. A quantitative estimate of the isovector E2 resonance strength for osmium is not attempted here because of uncertainties arising from both the extrapolation of the predicted E1 cross section above 21 MeV in the present instance and from the neutron multiplicity correction procedure.

The overall agreement between experiment and theory in the GDR region can be regarded as satisfactory. The extra experimental strength seen on the low energy side in Fig. 1 has been observed for other nuclei in previous comparisons involving earlier versions of collective excitations theory (see e.g. Deague *et al.* 1969). The integrated cross section for natural osmium from 6 to 27 MeV was found to be $2{\cdot}7 \pm 0{\cdot}3$ MeV.b. This is in good agreement with the classical dipole sum rule prediction of 2·76 MeV.b. The neutron emission usually exhausts the classical sum rule for medium and heavy nuclei in the GDR region where any charged particle emission is strongly inhibited by the Coulomb barrier.

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