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REPORT TO THE DOE NUCLEAR DATA COMMITTEE
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A. NUCLEAR DATA APPLICATIONS - MEASUREMENTS

The neutron emission spectra from ${}^6\text{Li}$, ${}^6\text{LiD}$ and ${}^7\text{Li}$ have been measured using the sphere transmission and time-of-flight (TOF) techniques for 14-MeV incident neutrons from the Livermore Insulated-Core-Transformer (ICT) accelerator. The radius of the spheres, 16.52 cm, corresponds to 1.1 mean-free paths (mfp) for the ${}^6\text{Li}$ and ${}^7\text{Li}$ spheres and to 1.93 mfp for the ${}^6\text{LiD}$ sphere for 14-MeV neutrons. The neutron emission spectra from a 0.8 mfp Be sphere ($R = 12.58$ cm) and 1.8 mfp CF_2 sphere ($R = 16.52$ cm) have also been measured. Be, used as a neutron multiplier in the tritium breeding blanket, can be present in metal form, as a fluoride (molten salt blankets: LiF (47%), BeF_2 (53%) composition, known as "flibe"), or as a lithium compound ($\text{Be}_2\text{Li}_2\text{O}$).

Overall, the ENDF/B-V calculation for the ${}^6\text{Li}$ spheres is in better agreement with the measurements than the ENDL, with discrepancies no larger than 20% in the energy region 8 - 12 MeV of the emitted neutrons. The calculations for ${}^6\text{LiD}$, ${}^7\text{Li}$, Be and CF_2 spheres show discrepancies of 20 to 30% with the measured spectra in the energy distribution of the neutrons below the source peak. A detailed analysis of the elastic, inelastic, and total cross sections for these materials is being carried out to understand the discrepancies.

Elastic and inelastic differential cross sections have been measured for Be, C, Al, Fe, Co, Ta and Bi at 14.4 MeV incident energy. The source neutrons are produced at the LLNL Cyclotrograph facility by the $^2\text{H}(\text{d},\text{n})^3\text{He}$ reaction using 12 MeV deuterons onto a 3.13 cm-long gas cell, 1 cm diam., pressurized to 2 atmospheres of deuterium. This cell is one of two identical cells mounted in a flip-flop mechanism which allows alternate measurements to be carried out with "gas-in" and "gas-out." The scattering samples are cylinders, 2.54 cm diam. by 5.08 cm high, and are suspended vertically 20 cm beyond the end of the cell. Scattered neutrons are detected using the neutron time-of-flight facility with sixteen NE213 scintillator detectors (11.4 cm diam. by 5.1 cm long) covering the angular region from 3 to 159° with a 10.75 m flight path. The detectors are shielded from the direct neutron source by a set of wedges (30 cm Pb and 70 cm Fe) positioned radially around the scattering sample.

The measured elastic neutron differential cross sections corrected for multiple scattering are in excellent agreement with measurements found in the literature.^{1,2} The main purpose of these measurements has been to test the new experimental facility: twin gas cells, tritium handling, and shielding in preparation for neutron scattering measurements up to 35 MeV using the $^3\text{H}(d,n)^4\text{He}$ reaction with deuterons up to 20 MeV available at this facility.

3. The Angular Distribution of Photoneutrons for ^{17}O (Phillips, Rowley, Woodworth, Jury*, Watson*)

We have measured the photoneutron cross section of ^{17}O leaving ^{16}O in its ground state. Electron bremsstrahlung was used as the photon source with electron energies of 15, 17, 21, and 25 MeV. The angular distribution of photo neutrons was measured at 7 angles from 22-1/2 to 157-1/2 degrees. The ^{17}O cross sections were measured relative to the ^2H cross section. The data are being analyzed to obtain additional information on the quantum numbers of the isolated resonances below the giant dipole resonance in ^{17}O . Information on the giant dipole will also be obtained from the highest energy measurement.

4. Photoneutron Cross Sections for ^{29}Si and ^{30}Si (Pywell,** Thompson,*** McNeill,⁺ Jury,* Woodworth, Berman)

Following previous photoneutron-yield measurements carried out at Melbourne, we have measured the photoneutron cross sections for ^{29}Si and ^{30}Si from 13 to 33 MeV with monoenergetic photons produced by the annihilator in flight of fast positrons from the LLNL 100 MeV Linear Accelerator. The (γ,n) cross section for ^{29}Si is relatively smooth, owing to its non-zero spin, and exhibits a giant dipole resonance (GDR) about 4 MeV wide, centered at 21 MeV. The $(\gamma,2n)$ cross section for ^{29}Si was consistent with zero from its threshold at 25.7 MeV to the highest energy measured. The GDR for ^{30}Si , as seen in the total photoneutron cross section $\sigma[(\gamma,n) + (\gamma,2n)]$, exhibits more structure, with peaks at about 17.5, 19.5, 20.5 and 22.5 MeV. The (γ,n) cross section drops to very small values a few MeV above the $(\gamma,2n)$ threshold at 19.1 MeV, then rises again as the $(\gamma,2n)$ cross section falls with increasing energy above its peak at about 23 MeV. This behavior has never been seen before, and probably indicates the increasing dominance of the (γ,pn) cross section a few MeV above its threshold at 22.9 MeV.

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1 Matoba *et al.*, Nucl. Phys. A 204, 129 (1973).

2 M. Hyakutake *et al.*, Jour. Phys. Soc. of Japan 38, 606 (1975).

5. Continuum Charged-particle Emission from Reactions Induced by Neutrons, Protons and Alpha-particles (Vonach*, Haight)

According to the Bohr hypothesis, a compound nucleus does not remember how it was formed except for the conservation of angular momentum. To test this hypothesis as well as to obtain more accurate level density information, we are studying the decay modes of the excited ^{51}Cr compound nucleus. In previous studies this nucleus was formed by 15 MeV neutrons on ^{50}Cr and the charged-particle emission spectra were measured.³ Neutron emission following neutron bombardment of ^{50}Cr has not yet been measured but is technologically quite possible. We are now forming the ^{51}Cr compound system at the same excitation energy by alpha-particles on ^{47}Ti and protons on the rare isotope ^{50}V . The isobars ^{50}V and ^{50}Cr are related by such a slow beta-decay that both are found in nature. This unusual situation allows study of the same compound system $^{51}\text{Cr}^*$ by neutrons or protons incident on ^{50}Cr or ^{50}V respectively. Information on the angular momentum dependence is given by the ^{47}Ti plus alpha reaction products.

6. Coupled-Channel Calculations of Neutron Elastic and Inelastic Scattering on $^{76,80,82}\text{Se}$ (Brown, Grimes,** Madsen†, Poppe, Wong)

Using the Oregon State Coupled-Channel Code,⁴ we have calculated⁵ the elastic and 2+ inelastic scattering of 3 MeV neutrons on $^{76,80,82}\text{Se}$. Our calculations differ from previous work⁶ in that we couple in explicitly the two-phonon states. Our fits to the neutron scattering data⁶ result in a more reasonable value of 18.5 MeV for the imaginary isovector surface strength as compared to the previous value of 38 MeV.⁶ The smaller imaginary isovector strength and the values of other optical parameters have been verified by calculating the $^{76,80,82}\text{Se}(p,n)$ reaction to the ground isobaric analog state and comparing with recent measurements at 19 MeV.⁷ The good agreement (see Fig. A-1) confirms the validity of the smaller imaginary isovector strength and the importance of coupling in the two-phonon states in the selenium isotopes.

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3 S.M. Grimes, R.C. Haight, K.R. Alvar, H.H. Barschall and R.R. Borchers, Phys. Rev. C19, 2127 (1979).

4 M.J. Stomp, F.A. Schmittroth and V.A. Madsen, USAEC Technical Report, Contract No. AT(45-1)-2227, Task Agreement No. 11 (unpublished).

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6 J. Lachkar et al., Phys. Rev. C14, 933 (1976).

7 C. Wong, S.M. Grimes, C.H. Poppe, V.R. Brown and V.A. Madsen (UCRL-87165) (to be published in Phys. Rev. C).

FIG. A-1. Measured and calculated angular distributions for the excitation of the 0^+ analog states in $^{76,80,82}\text{Se}$ (p,n) by 19 MeV protons. The neutron optical model parameters were derived from an analysis of neutron elastic and inelastic scattering data.

7. Neutron-Capture Resonances for ^{82}Se (Browne,* Berman)

We have investigated neutron capture resonances for ^{82}Se using the white neutron source from the LLNL 100 MeV Linac. Strong neutron-capture resonances for ^{82}Se were found at 3.63, 7.1, and 9.51 keV and weaker ones at 0.58, 1.15, and possibly 13.54 and 16.5 keV. None was found at lower neutron energies. Energies have been assigned to neutron-capture resonances up to 40 keV for all the other selenium isotopes as well.

8. Measurement of Fast-Neutron Cross Sections for ^{88}Y , ^{88}Zr , and ^{168}Tm (Nethaway, Smith, Prestwood,** Thomas**)

We have made several measurements of fast-neutron cross sections for the radioactive target materials ^{88}Y , ^{88}Zr , and ^{168}Tm . These measurements are difficult to make because of the intense radioactivity associated with their relatively short half-lives. The experimental results are valuable because they provide additional tests of the nuclear models used in the calculation of cross sections for neutron-deficient nuclides.

The tracer materials were produced by spallation of molybdenum and tantalum targets with 800-MeV protons at the Isotope Production Facility at LAMPF. The tracers were allowed to age until the short-lived products ^{87}Y and ^{167}Tm had decayed to negligible levels. We used targets containing up to 40 mCi ^{88}Y , 140 mCi ^{88}Zr , and 15 mCi ^{168}Tm . The fast-neutron irradiations were made at the ICT and RTNS-II facilities at Livermore, using neutrons in the 14-15 MeV range.

The ^{88}Y and ^{88}Zr measurements were made on the daughter nuclide ^{87m}Sr , which was separated as a function of time from Y and Zr fractions from the ^{88}Zr target, and from the ^{88}Y target itself. The ^{167}Tm measurements were made on the mass-167 fractions following single and double isotope separations of the ^{168}Tm target. Preliminary results are given in Table A-1.

9. Intermediate States in Nuclear Fission (Becker)

Nuclear states in the second minimum of the fission barrier reflect themselves in broad resonance structures in fission excitation functions and in anomalous fragment angular distributions. To study these intermediate states, we have measured simultaneously the excitation function and fragment angular distribution for the $^{232}\text{Th}(n,f)$ reaction, with a resolution of 0.16 nsec/m. A "white" neutron source produced by the Lawrence Livermore National Laboratory 100-MeV Electron Linac irradiated a thick ^{232}Th sample. Fission fragments were detected in a new array of multi-wire position sensitive counters designed to yield fragment angular distribution information.

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The angular distributions, extracted after normalization to data collected with a ^{235}U (93%) foil in the place of the ^{232}Th sample, were parameterized by a Legendre Polynomial expansion, $W(\theta) = I_0 (1 + A_2 P_2(\cos\theta) + A_4 P_4(\cos\theta))$. The coefficients for different incident neutron energy regions obtained in a preliminary analysis are presented in Table A-2. Note that the angular distribution associated with the photofission process is peaked at 90° as expected, and that as the incident neutron energy increases over the second-chance fission threshold, the angular distribution becomes strongly forward peaked. In the region of $1.2 \leq E_n \leq 2$ MeV, the angular distribution exhibits both positive and negative coefficients. Further analyses and comparisons with other work are continuing.

10. Excited Levels of ^{250}Bk From Spectroscopic Measurements of $^{249}\text{Bk}(n,\gamma)$, ^{250}Bk and $^{249}\text{Bk}(d,p)^{250}\text{Bk}$ Reactions (Hoff, Loughheed, Lanier, White,* Borner,** Davidson,** Schreckenbach,** Warner,** von Egidy,** Kouzes,+ Naumann,+ Dewberry+)

The gamma rays and conversion electrons emitted following neutron capture in ^{249}Bk targets have been measured by use of the GAMS, BILL, and three-crystal pair spectrometers at Grenoble. We have measured the proton spectrum from the $^{249}\text{Bk}(d,p)^{250}\text{Bk}$ reaction by use of a QDDD spectrometer at the Princeton AVF cyclotron. The data from these measurements have been combined with those from earlier studies of ^{254}Es alpha decay⁸ to produce a more detailed level scheme for ^{250}Bk than before. Although the interpretation of our experimental data is not complete, we have identified 23 excited levels in ^{250}Bk (see Table A-3).

The average deviation between experimental bandhead energies for eight of these nine bands and values calculated from a simple model involving addition of excitations observed in neighboring odd-mass nuclei is 11 keV. Values for the Gallagher-Moszkowski splitting of each configurational pair were obtained from theoretical calculations.⁹

It is possible to distinguish unambiguously between the only two proton states used in the configuration assignments, $7/2[633]$ and $3/2[521]$, because of the large difference in rotational parameters. For the four configurational pairs observed in ^{250}Bk , the moment of inertia for each band with antiparallel alignment of odd-nucleon momenta is systematically larger than for its parallel-aligned mate. It is not clear whether this is a general phenomenon or peculiar only to the ^{250}Bk level scheme.

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9 R. Piepenbring and J.P. Boisson, private communication (1978).

TABLE A-1. Preliminary results of fast-neutron cross sections measured for ^{88}Y , ^{88}Zr , and ^{168}Tm .

Reaction	Neutron energy (MeV)	Cross sections (mb)
$^{88}\text{Y}(n,2n)^{87}\text{Y}$	14.1	1140 ± 60 (a)
	14.8	1180 ± 60 (a)
$^{88}\text{Zr}(n,2n)^{87}\text{Zr}$	14.8	467 ± 24
$^{88}\text{Zr}(n,np)^{87}\text{Y}$	14.8	257 ± 26
$^{168}\text{Tm}(n,2n)^{167}\text{Tm}$	14.5	2100 ± 110

(a) The ^{87}Y isomer ratio, $m/(m+g)$, was measured to be 0.72 ± 0.05 .

TABLE A-2. Angular distribution coefficients obtained in the $^{232}\text{Th}(n,f)$ reaction

E_n (MeV)	ΔE_n (MeV)	A_2	A_4
1.2	0.1	0.56 ± 0.34	-0.19 ± 0.45
1.3	0.1	0.40 ± 0.19	-0.41 ± 0.25
1.4	0.1	0.27 ± 0.16	-0.28 ± 0.21
1.5	0.1	-0.21 ± 0.12	-0.35 ± 0.17
1.6	0.1	-0.21 ± 0.12	-0.18 ± 0.16
1.7	0.1	0.43 ± 0.17	-0.57 ± 0.23
1.8	0.1	0.34 ± 0.08	-0.08 ± 0.02
1.9	0.1	0.11 ± 0.17	0.18 ± 0.24
3.0	1.0	0.10 ± 0.08	-0.02 ± 0.10
4.0	1.0	0.16 ± 0.10	0.11 ± 0.13
5.0	1.0	0.28 ± 0.11	-0.16 ± 0.15
6.0	0.5	0.56 ± 0.16	0.35 ± 0.18
6.5	0.5	0.44 ± 0.13	0.28 ± 0.16
7.0	0.5	0.69 ± 0.15	-0.06 ± 0.18
7.5	0.5	0.37 ± 0.14	0.22 ± 0.18
8.0	0.5	0.43 ± 0.19	-0.05 ± 0.23
8.5	1.5	0.39 ± 0.12	-0.01 ± 0.16
"photo-fission"		-0.32 ± 0.03	-0.06 ± 0.04

TABLE A-3. Experimental levels in ^{250}Bk and comparisons with simple model predictions.

Configuration	Bandhead energy(keV)		Rotational band levels		$\hbar^2/2J$ (keV)	
	Exp.	Model	I	E(keV)	Exp.	Model
$3/2^- [521]_p + 1/2^+ [620]_n$	0	0	2^-	0	5.77	5.72
			3^-	34.472		
			4^-	80.258		
			5^-	137.32		
$3/2^- [521]_p - 1/2^+ [620]_n$	104	109 ± 5	1^-	103.828	5.35	5.72
			2^-	125.007		
			3^-	157.391		
			4^-	203.637		
$7/2^+ [633]_p + 1/2^+ [620]_n$	36	40 ± 18	4^+	35.587	4.31	4.26
			5^+	78.326		
			6^+	130.492		
$7/2^+ [633]_p - 1/2^+ [620]_n$	115	96 ± 18	3^+	115.442	4.14	4.26
			4^+	148.595		
$3/2^- [521]_p + 7/2^+ [613]_n$	97	101 ± 30	5^-	97.493	5.80	5.88
			6^-	167.089		
$3/2^- [521]_p - 7/2^+ [613]_n$	146	144 ± 30	2^-	146.472	5.59	5.88
			3^-	179.990		
$7/2^+ [633]_p - 7/2^+ [613]_n$	175	107 ± 35	1^+	175.123	--	4.34
			0^+	215.944		
$7/2^+ [633]_p - 3/2^+ [622]_n$	212	213 ± 23	2^+	211.822	4.18	4.37
			3^+	236.739		
			4^+	270.461		
$7/2^+ [633]_p + 3/2^+ [622]_n$	316	295 ± 23	5^+	316.463	4.43	4.37
			6^+	369.61		

B. NUCLEAR DATA APPLICATIONS - CALCULATIONS

1. Development of Microscopic Optical Model for Neutron Elastic Scattering, with Application to ^{208}Pb (Dietrich, Howell, Phillips, Petrovich,*)

We have developed the capability of performing microscopic optical model calculations based on the folding of a complex density- and energy-dependent effective interaction with the nuclear density. The aim of these calculations is to reduce the number of parameters in this conventional optical model description, and ultimately to improve our understanding of the relation between the neutron and proton optical models and the (p,n) quasi-elastic reaction. The general approach is due to that of Brieva and Rook.¹ The free parameters that are adjusted to data are normalization factors for the real and imaginary central potentials and the real spin-orbit potential generated by the folding procedure. Fig. B-1 shows a fit to 25.7-MeV data for neutron scattering from ^{208}Pb . The central part of the effective interaction is that of Brieva, Rook, and von Geramb,² and the spin-orbit force from the M3Y interaction.³ The nuclear charge density was taken as a two-parameter Fermi function fit to electron scattering,⁴ and the neutron and proton densities were assumed to be proportional.

The quality of the fit is comparable to that with conventional optical models that use a common geometry over a wide energy range. The normalizing factors were 1.07, 0.92, and 1.28 for the real, imaginary and spin-orbit potentials, respectively, which indicates reasonable consistency of the model, at least at this energy. A test of the model over a wide neutron energy range (7 to 40 MeV) is presently under way.

2. A Strength Function Method for Calculating Level-densities (Bloom, Vonach,** Grimes,*** and Hausman)

A new method for calculating level densities based on the Lanczos algorithm,⁵ with the addition of a Monte Carlo (statistical) technique for sampling the full set of eigenvectors modeling the nucleus, has been developed and applied to the positive parity levels of ^{28}Si . A realistic Hamiltonian is used to generate the

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2 H.V. von Geramb, F.A. Brieva, and J.R. Rook in Microscopic Optical Potentials, H.V. von Geramb, ed., Lecture Notes in Physics No. 89, Springer Verlag, Berlin, 1979, p.104.

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4 D. E. Bainum et al., Phys. Rev. C16, 1377 (1977).

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FIG. B-1. Calculated angular distribution of 25.7 MeV neutrons elastically scattered by ^{208}Pb . The optical potential was obtained by the folding model. The experimental data are from Ref. 4.

sampled model space. The number of levels in the model for ^{28}Si was 69,000; a rather large statistical sample of 24,000 states was used in these calculations. Spin cutoff parameters have also been calculated.

Preliminary comparisons with experimental data are quite encouraging for the level densities calculated at excitation energies of 8-15 MeV. In this region the calculated level densities are expected to be independent of the model size.

3. Parameterization of the E1 Strength Function (Gardner, Gardner)

The reparameterization of an energy-dependent Breit-Wigner model of the E1 gamma-ray strength function, $f_{E1}(E)$, has been investigated using a more general expression for the Breit-Wigner line shape function, $G(E_\gamma, E_R, \Gamma_R)$. For a giant dipole resonance (GDR) with one peak or two peaks of equal height,

$$f_{E1}(E_\gamma) = 3.3 \times 10^{-6} \frac{NZ}{A} \frac{F_{SR}}{E_\gamma} \frac{\sum_i G_i(E_\gamma, E_{Ri}, \Gamma_{Ri})}{\sum_i \Gamma_{Ri}} \text{ MeV}^{-3}$$

Here E_R and Γ_R are the peak energy and width of the GDR, and E_γ is the gamma-ray transition energy. F_{SR} incorporates the extent to which the dipole sum rule is exhausted. For neutron and low-energy proton capture, we define this in terms of the isospin splitting of the GDR, $F_{SR} = [T_0 / (T_0 + 1)] [1 + 3/2 A^{-2/3}]$, where $T_0 = (N-Z)/2$.

The line shape function now employs a product of a constant width, Γ_R , and an energy-dependent width, $\Gamma(E_Y)$

$$G(E_Y, E_R, \Gamma_R) = \frac{\Gamma_R \Gamma(E_Y) / 4}{(E_Y - E_R)^2 + \Gamma_R \Gamma(E_Y) / 4}$$

The energy-dependent width has the form

$$\begin{aligned} \Gamma(E_Y) &= \Gamma_R E_Y^2 \left(\frac{2}{E_x + E_R} \right)^2 & ; & \quad E_Y \leq (E_x + E_R) / 2 \\ &= \Gamma_R & ; & \quad E_Y > (E_x + E_R) / 2 . \end{aligned}$$

There is one free parameter, E_x , for which the value of 5 MeV seems to fit a wide range of masses. The E_Y^2 dependence of $\Gamma(E_Y)$ tends to agree with a number of experimental photoabsorption measurements. In addition, we have compared our new predictions with the extensive survey of dipole radiative strength functions derived from neutron resonance data by McCullagh, Stelts and Chrien.⁶ This comparison is shown in Fig. B-2, where the E1 strength function is expressed as

$$S_{E1} = f_{E1}(E_Y) E_Y^{-2} A^{-8/3}.$$

The dashed-line band shows a range of calculated values from our original treatment.⁷ The solid line shows the present results which constitute a significant improvement, although the new parameterization may still overpredict the magnitude of f_{E1} by about 30% in some mass ranges.

4. Evaluation of Macroscopic Fission Barrier Models (Blann, Komoto)

Fission barriers may be represented as the sum of a microscopic and macroscopic component. The microscopic component is related to the position and spacing of single particle levels as a function of nuclear deformation; the macroscopic component is related to the interplay between coulomb and surface energies versus nuclear deformation. Below $Z \approx 82$ the macroscopic component is much larger than the microscopic component; therefore this region is well suited to testing macroscopic barrier models. However significant fission cross sections result in $Z < 82$ nuclides only when moderately large angular momenta are present, e.g., in heavy ion induced reactions.

⁶ C.M. McCullagh, M.L. Stelts, and R.E. Chrien, Phys. Rev. C23, 1394 (1981).

⁷ D.G. Gardner, M.A. Gardner, and F.S. Dietrich, "A Study of Gamma-Ray Strength Functions," UCID-18759 (August 7, 1980).

FIG. B-2. E1 strength function as a function of atomic mass numbers. The dashed band is from the original energy-dependent Breit-Wigner model.⁷ The solid line is the result of the pressed model. Experimental data points are from McCullagh *et al.*⁶

The main model invoked to predict the macroscopic barriers versus angular momenta is the rotating liquid drop model (RLDM).⁸ This has been found in many comparisons with data to overestimate the angular momentum dependent fission barriers.⁹ The errors were qualitatively in the direction predicted by Krappe *et al.*, due to finite range effects at the saddle point; however the latter correction was predicted only for non-rotating nuclei, making comparisons with results deduced for rotating systems unclear.¹⁰

We have analyzed a large body of (HI,f) data with a new Hauser-Feshbach code in order to determine the magnitudes of differences between macroscopic fission barriers and the RLDM predictions. These barrier decrements may be compared to first order with finite range model predictions if the abscissa is a total disruptive parameter consisting of both coulomb and centrifugal components. A comparison is shown in Fig. B-3 between predictions of the finite range model and experimentally deduced decrements from RLDM barriers. A very strong correlation may be seen, with a suggestion that the finite range correction may be around 1 MeV low in the parameter range of comparison.

⁸ S. Cohen, F. Plasil and W.J. Swiatecki, Ann. Phys. (N.Y.) **82**, 557 (1974).

⁹ M. Beckerman and M. Blaun, Phys. Rev. **C17**, 1615 (1978).

¹⁰ H.J. Krappe, J.R. Nix and A.J. Sierk, Phys. Rev. **20**, 992 (1979).

FIG. B-3. Corrections deduced to RLDM barriers for various compound systems versus the effective Z^2/A of the compound systems. The solid curve is the finite range correction prediction of Ref. 10, calculated for stable nuclei. The dashed curve is the lower finite range correction prediction of Ref. 10.

A detailed description of the calculations performed, computer code capabilities, and range of data analyzed has been reported.¹¹ The present results suggest that extensions and refinements of the finite range approach may provide a good basis for more accurate macroscopic descriptions of the fission process.

5. Fission Barriers of Rotating Nuclei (Mustafa, Baisden, and Chandra)

Fission barriers of rotating nuclei have been calculated with a new macroscopic model.¹² The model explicitly includes the effects of the finite range of nuclear forces and diffuse nuclear surface in all the terms contributing to fission barriers. The model also allows for triaxial shape variations and a continuous transition from ground state to saddle to scission shapes.

¹¹ M. Blann and T. Komoto, "Statistical Fission Parameters for Nuclei at High Excitation and Angular Momenta," UCRL-87112 (1982).

¹² M.G. Mustafa, P.A. Baisden, and H. Chandra, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-85260. Rev. 1, (1982).

The predictions of our model can be tested by heavy-ion experiments and utilized in the de-excitation of a compound nucleus by particle emission and fission.

C. NUCLEAR DATA FOR REACTOR SAFETY

1. Determination of Fission Yields by Continuous Chemistry (Meyer, Henry, Massey, Rengan)

We have used our ethylene gas-jet system^{1,2} to measure independent fission yields of short-lived selenium fission products. In these experiments, a mixture of ethylene and nitrogen was used to thermalize and carry the fission products from a ^{235}U target chamber in a gas jet. The selenium isotopes of mass 83-88 were selectively collected in a quartz-wool trap in about 750 ms after fission (or later when an additional delay line is used).³ The gamma-ray spectra of the mixture of selenium isotopes obtained under equilibrium conditions were used to determine the fission yield of ^{85}Se . Using the known ^{84}Se yield, the absolute yield of ^{85}Se was calculated.

Results of three different experiments were used. The collection of Se started at 750, 870, and 940 ms, respectively. A correction for the decay of As precursors during the time before collection was made on the assumption that the Se species, formed as a result of As decay, behave similar to those formed directly in fission. The values for the independent yields of ^{85}Se to ^{88}Se are summarized in Table C-1. The independent-yield values calculated for ^{85}Se from the three experiments with different delays agree fairly well with each other and with the value reported by Kratz and Herrmann.⁴

2. Experimental Test of High-Energy Beta Strength Functions: S_{β} for $^{84}\text{As}(8)^{81}\text{Se}$ with Q_{β} of Approximately 10 MeV (Henry, Lien, Meyer)

We have used the AUTOBATCH fast chemistry system⁵ to isolate rapidly the short-lived As isotopes from mixed fission products. Over 10,000 targets were irradiated, chemically separated, and counted during the ^{84}As gamma-ray coincidence and high-energy singles experiments.

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- 1 Nuclear Chemistry Division Annual Report, UCAR-10062, p. IV-B-2, 1980.
 - 2 R.A. Meyer, Energy & Technology Review, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-52000-80-5 (1980) p.8.
 - 3 K. Rengan, J. Lin, T.N. Massey, M. Zendel, and R.A. Meyer, submitted to J. Inorg. Nucl. Chem. (1981).
 - 4 J.V. Kratz and G. Herrmann, IAEA Symp. Phys. Chem. Fission, 2, 95 (1973).
 - 5 O. G. Lien, P. C. Stevenson, E. A. Henry, R. P. Yaffe, and R. A. Meyer, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-84371 (1980) Nucl. Inst. and Methods (in press).

TABLE C-1. Fission Yields of Short-Lived Selenium Isotopes

Delay (milliseconds)	Independent Yield			
	85-Se (31s)	86-Se (15s)	87-Se (5.6s)	88-Se (1.5s)
750	0.97	0.68	(0.0662·B) ^b	(0.0537·C) ^b
870	0.99	0.72	(0.0666·B) ^b	(0.0537·C) ^b
940	1.00	0.72	(0.0668·B) ^b	(0.0552·C) ^b
Literature (Batch-Chem)	1.08	None	None	None
Precursor Half life	2.03s	0.9s	0.3s	Unk.

^a All values have an error of approximately 5%.

^b The final value for these await the determination of the absolute intensity of the respective fiducial gamma ray: B is 468-keV gamma-ray absolute intensity of ⁸⁷Se, and C is the 158-keV gamma-ray absolute intensity of ⁸⁸Se.

The experimental beta strength function deduced from the ⁸⁴As decay scheme can be compared to that calculated by a statistical model where the beta strength function is assumed to be proportional to the level density (calculated using the Gilbert and Cameron formalism⁶). The most significant differences are that the experimental beta transition intensity has an excess of about 16% near 2700 keV and a deficit of the same size above 6.8 MeV compared to calculated beta transition intensities. Above 7.0 MeV the calculated beta intensity is approximately four times that which can be estimated by the procedures described below. Over the energy range from 3 to 6.8 MeV the experimental beta strength function deduced from discrete gamma rays fluctuates about but follows the general trend of the calculated strength function.

Since a large part of the beta strength function at all energies is determined by gamma rays which populate the 1455-keV level, the gamma rays in coincidence with the 1455-keV level can serve as a useful probe to determine if the general shape of the spectrum of gamma rays into this level can be reproduced by a statistical model.

⁶ A. Gilbert and A.G.W. Cameron, Can. J. Phys. 43, 1446 (1965).

Shown in Fig. C-1 is a comparison of the experimental gamma-ray intensity into the 1455-keV level compared to that calculated using the statistical beta strength function. It is assumed in the calculation that levels with $J = 3, 4$, and 5 are populated by the beta decay and that these levels decay by dipole transitions. Above 5 MeV of excitation, levels were grouped into 200 keV bins, while below 5 MeV the experimental levels were used in the calculation. The total intensity into each bin or level included the beta intensity and the sum of all gamma-ray intensity from higher levels. It is seen that such a calculation cannot account for the observed gamma-ray intensity into the 1455-keV level.

The gross coincidence spectra of other strong gamma rays show results similar to, though less easily quantifiable than those indicated by the 1455-keV coincidence gate. They show in most cases a discontinuity at a gamma-ray energy commensurate with an excitation energy of 6.5 MeV. These quantitative and qualitative results from the gross coincidence spectra indicate that the experimental beta strength functions derived from discrete gamma rays underestimate the strength near 6.5 MeV. No evidence is found for sufficient additional gamma-ray intensity to account for all of the 16% beta intensity discrepancy between experiment and calculation above 6.8 MeV. Finally, we observe that the gamma-ray intensity distribution to low-lying levels is not reproduced by a statistical distribution.

FIG. C-1. Comparison of experimental gamma-ray intensity into the 1455-keV level to that calculated using a statistical beta strength function.

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