EANDC(US)-107 "A"
INDC(US)-4 "G"

Preliminary Draft of a Status Report on Heavy-Element Cross Sections

by M. S. Moore

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Summary

A survey is made of work presently being conducted in the United States, in the United Kingdom, and in western Europe, on measurements of nuclear cross sections of actinide isotopes which may be of interest to the applied US nuclear energy program. This survey covers primarily laboratories which submit reports to the Nuclear Cross-Sections Advisory Committee and to the European-American Nuclear Data Committee, and is based on activities currently being pursued and work which is planned for the immediate future. Appended to the report is a summary listing of those entries in the US request compilation (WASH-1078) which may be directly affected by the experimental efforts being carried out. Comments are also made on certain requests for which work is not presently being done.

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This report has been prepared as follows: Status reports to NCSAC and to EANDC, and reports of recent meetings were consulted to determine which activities of various US, UK, and European laboratories might be appropriate to the report. Whenever it appeared that a substantial effort is being made on the measurement of cross sections of isotopes in the actinide region (especially where it appears that these measurements may be directly applicable to an entry in the US request compilation), an effort was made to contact the appropriate laboratory representative in order to give a more complete picture of the current status. The measurements in progress at laboratories outside the US are included only insofar as they have been reported at conferences and meetings or in status reports.

Reports consulted include the following as primary references:

(1) WASH-1079, EANDC(US)104"U". Reports to the NCSAC, October 1967.

(2) WASH-1093, EANDC(US)105"U". Reports to NCSAC, April 1968.

(3) EANDC(E)89"U", Euratom Status Report, January 1968.

(4) EANDC(UK)91"AL", United Kingdom Status Report, to mid-1967.

Argonne National Laboratory

In WASH-1079 and WASH-1093, Meadows reported a measurement of mass, energy, and angle, for 6 MeV neutron-induced fission of U-235 and U-238, respectively. No interdependence of mass and angle was observed. Braid et al are studying energy levels of U-235 and other odd-A actinides with (d,p) and (d,t) reactions.

De Volpi is measuring $\bar{\nu}$ absolutely, by an improved manganese bath technique, for Cf-252. Preliminary results and surveys of the technique were submitted to the second NCS & T Conference in Washington, D. C. (Papers B-9 and B-12). At the same conference, Poenitz reported measurements of the fission cross section of U-235 from 3 to 1500 keV. Normalized at 30 keV, the slope deviates from the generally accepted curve, being about 15% low at 1 MeV. (Paper D-5) A description of this work is also contained in WASH 1093.

Huizenga et al reported preliminary results of a study of Th-232 (n,f) angular distributions at 1.2, 1.4, and 1.6 MeV. The data will give information on the systematics of fission channel structure at and near threshold. A paper describing additional studies for Pu-239(n,f) was submitted to the NCS & T Conference in Washington, D. C. (Paper D-16).

At the Madison APS Nuclear Physics Division meeting, Kuchnir et al reported measurements of the differential cross section and the polarization in the elastic scattering of neutrons from U and Th at 0.6 to 1.2 MeV at small angles (1.75 to 15°). [Bull. Am. Phys. Soc. 12, 1187 (1967).] A description of this work is also contained in WASH-1093.

Also in WASH-1093, Lister reports work on the capture cross section of U-236 from 30 to 1000 keV with Ge(Li) detectors. Whalen et al report an 8-10% discrepancy from BNL-325 in the total cross section of Th-232 from 100 to 650 keV.

Diamond et al reported fission cross section measurements, in a thermal column, for Pu-243, Bk-250, Cm-247, Cm-245, Es-254m, and Es-254. Parameters were reported for low-energy s-wave resonances of Th-232, by Hla Shwe et al, NCS & T Conference in Washington, D. C. (Paper E-30).

Brookhaven National Laboratory

Sailor et al report plans for measurements on the determination of spin states in U-235, by capture of polarized neutrons by polarized target nuclei

This presumably will be an extension of studies reported by Shermer et al [Phys. Rev. 167, 1121 (1968)].

Chrien reported on radiative capture of resonance energy neutrons in U-238 at the Madison meeting of the APS Nuclear Physics Division. [Bull. Am. Phys. Soc. 12, 1167 (1967).] The study of high energy gamma rays from the low-lying resonances in Th-232 was discussed in WASH-1093. Gordon and Weinstock reported an upper limit to the resonance absorption integral of Cf-252, as < 100 barns.

Columbia University

Melkonian and co-workers are continuing studies of fundamental properties of fission, including correlated energy and time-of-flight determinations of mass yields, comparison of mass distributions of Pu-240* at various excitations, and variation of ternary fission yields from resonance to resonance for U-233 targets.

Gulf General Atomic

Measurements of the radiative capture cross section of U-236 are continuing. Preliminary results from 0.01 to 200 eV were reported by Carlson et al at the 1967 winter meeting of the APS [Bull. Am. Phys. Soc. 12, 1124 (1967).] Preliminary parameters are given in WASH-1093. Also reported by Verbinski et al, are measurements of prompt fission gamma spectra of U-235 and Pu-239, with a NaI spectrometer.

Idaho Nuclear Corporation

The absolute determination of eta for Pu-241 by the Mn-bath technique at 0.025 and 0.06 eV is undergoing final analysis. Measurements were also repeated on U-233, U-235, and Pu-239 at these energies to check previous work. Preliminary results were reported by Smith at the NCS & T Conference in Washington, D. C. (Paper D-14). Techniques for a measurement of alpha for Pu-239 at 2 keV are under development. A Mn-bath determination of eta

at 2 keV, combined with the accepted (thermal) value of $\bar{\nu}$ will yield a 5 to 10% value for alpha. The relative fission and absorption cross sections will also be determined with a total absorption gamma spectrometer.

The fast chopper total cross section measurement of Pu-242 has been completed, except for an inconsistency in the shape of the cross section at low energy (< 0.1 eV). Young et al will submit a paper describing this work within the next few weeks. Total cross section measurements on U-236 are continuing. Preliminary results show good agreement with previous measurements, on the 5.4 eV resonance. Total cross section data on Am-243 are being analyzed by graphic display techniques and some preliminary results are given in WASH-1093. Data obtained on Cm-244 are not significantly better than earlier work, and analysis will not be carried out until better data are obtained with a different sample. Samples of Pa-233 have been prepared, and high resolution total cross-section measurements are under way in the region above 20 eV. A sample of Th-230 has also been prepared, and measurements on this isotope will commence shortly. Measurements of the total and elastic scattering cross sections of U-233, U-235, and Pu-239 from 1 to 400 eV, made on the RPI linac, are still being analyzed to obtain resonance spin assignments.

Nuclear explosion data on the absorption cross section of Pu-238 are being analyzed. Rupture of the large (1.5 g) sample of Pa-233 just prior to time zero prevented the collection of high quality capture data for Pa-233 on the most recent experiment. Fission data were obtained above a few hundred keV.

Lawrence Radiation Laboratory (Livermore)

Spark-chamber fission cross section data on U-232 have been analyzed and will be published in the very near future. Scattering cross section measurements for U-233, U-235, and Pu-241 have also been virtually completed. A preliminary report of this work was made by Sauter and Bowman at the

NCS & T Conference in Washington, D. C. (Paper D-10), and details are given in WASH-1093.

Fission data on Pu-238 were obtained on the nuclear explosion "Pommard" and will be analyzed to determine the number of fission channels and the importance of the (n,γf) process in subthreshold fission of this nuclide. Subthreshold fission studies, to estimate the importance of (n,γf) and intermediate structure thought to be caused by fluctuations in the shape of the fission barrier, will be undertaken for U-234 and U-236.

Los Alamos Scientific Laboratory

Data obtained on the capture cross section of U-238 with a nuclear explosion source of neutrons were reported by Glass et al at the NCS & T Conference in Washington, D. C. (Paper D-13). Fission data on Cm-244 were reported by Fullwood et al at the same meeting (Paper D-12). At the Madison meeting of the APS Nuclear Physics Division, Silbert reported on the analysis of Pu-238 and U-235 fission cross sections and Pu-238 capture cross sections from the Persimmon shot. [Bull. Am. Phys. Soc. 12, 1167 (1967).] The most recent experiment (Pommard) provided fission cross section data on U-232, U-233, U-234, U-235, U-236, U-237, Pa-233, Np-237, Pu-238, Pu-242, Am-243, and Cm-243. Capture data were obtained for U-233, but the capture sample for Pa-233 was ruptured, and the data are presumed to be of only limited value. A group from AWRE obtained capture and fission data on Pu-239 and Pu-241 from about 40 eV to several MeV on this experiment. (Pu-239 fission inferred from $\bar{\nu}$.)

The fission cross sections of U-235 and U-238 have been measured below 20.5 MeV (Hansen et al) to an accuracy of 3%. Barton and Koontz are measuring fission ratios (to U-235) for Pu-238 and Cm-244 between 1.5 and 3.0 MeV. A discussion of this work was given at the NCS & T Conference in Washington, D. C. (Paper D-15). Also submitted to the same Conference was a paper by Stein et al (Paper D-19) discussing U-236, U-238, Np-237 fission ratios between 1 and 5 MeV.

The absolute delayed-neutron yield measurements reported in WASH-1079 for U-235, U-238, and Th-232 will be extended to other fissionable species. Grundl has measured fission neutron spectra from 0.8 to 16 MeV in U-235, U-238, and Pu-239. He finds fewer neutrons above 6 MeV and below 1.4 MeV than the usual Maxwellian description would give.

Studies of charged-particle induced fission (d,pf and t,pf), expected to give vital information on the systematics of neutron fission thresholds, are continuing. Preliminary reports of these data were included in WASH-1079 and were presented at the APS meeting in Chicago. [Britt and Rickey, Bull. Am. Phys. Soc. 13, 36 (1968).]

National Bureau of Standards

In WASH-1079, Schröder reported measurements of the prompt gamma and long range alpha coincidence distributions from spontaneous fission of Cf-252.

Oak Ridge National Laboratory

The ORNL-RPI measurements of alpha for U-233, U-235, and Pu-239 (Weston, deSaussure, and Gwin, respectively) are still in progress. Preliminary data on Pu-239 are being processed. Emphasis is now being placed on the Pu-239 and on making accurate measurements at very low energies ($\sim$ 0.2 eV), where hold-up of neutrons in the moderator may have introduced significant timing errors. Preliminary reports of this work were presented at the informal Reactor Physics Division session at the winter ANS meeting in Chicago, and are reported in WASH-1093.

Rensselaer Polytechnic Institute

Weinstein has extended the low energy U-235 $\bar{\nu}$ measurements to higher energies and is also taking data on U-233 and Pu-239, to establish the importance of a possible variation of $\bar{\nu}$ in the resonance region. A preliminary report of these data was submitted to the NCS & T Conference in Washington, D. C. (Paper D-20), and is discussed in the WASH-1093.

Texas Nuclear Corporation

In WASH-1093 Nellis et al report measurements of capture gamma spectra from 1 MeV neutron capture in U-238.

EURATOM, Geel

The EURATOM community is conducting a series of measurements at Geel, consisting of precision U-235 fission cross section measurements at thermal and in the resonance region. Migneco and Theobald report measurements of the fission cross section of U-235 from 6 eV to 3 keV; they will attempt fission and $\bar{\nu}$ measurements for U-233. Preliminary results were reported by Deruytter at the Second NCS & T Conference in Washington, D. C. (Papers D-2, D-3, and D-4). In EANDC(E)89"U" Deruytter reports fluctuations in the ternary-to-binary fission ratio for U-235, in agreement with previous measurements by Michaudon at Saclay.

The scattering, total, capture, and subthreshold fission of Pu-240 have been measured with the EURATOM linac, and complete parameters were determined for resonances below 820 eV. Preliminary reports of this work were also given at the NCS & T Conference (Papers D-6, D-7, D-8, and D-9). Plans are in progress for a similar series of measurements on Pu-241 partial and total cross-section measurements, to be carried out during the next year. Elastic scattering measurements were reported in EANDC(E)89"U" at 0.4, 0.3, 0.2 MeV for Pu-239.

An attempt will be made to compare the total-kinetic-energy and mass distributions for Pu-240 spontaneous fission with those for thermal-neutron-induced fission of Pu-239.

CEN, Saclay

Measurements are still in progress on total and subthreshold fission of Np-237. Preliminary results were reported at the NCS & T Conference by

Michaudon (Paper D-1). The Pu-239 total and fission measurements are virtually completed. Analysis of the data has some bearing on the Pu-239 alpha problem: using a Hill-Wheeler description of the 1+ channel, preliminary parameters are found to be $\hbar\omega$ = 500 keV, with the barrier location $\hbar\omega_0$ = +200 keV above the neutron binding energy. Studies are also commencing on the total kinetic energy of U-235 fragments in the resonance region, using a grilled ion chamber. Dabbs is planning to extend his low energy angular distribution studies of fragments from fission of aligned U-235 target atoms to higher resonances (< 22 eV) during the next year at Saclay. (Postma et al at the Petten Lab report plans to make similar measurements [EANDC(E)89"U".)

Thermal fission of U-235 is being studied by Nifenecker, who is seeking a correlation of angle and energy in ternary fission, studying mass distributions near symmetric fission, and planning a series of range-energy studies of fragment slowing down in VYNS foils. A study of fission-fragment X-rays is also planned.

Fast neutron work under Leroy will involve a measurement of the fission cross section of U-235 between 120 and 370 keV, using the calibrated fission chamber of P. H. White. Soleilhac is carrying out $\bar{\nu}$ measurements between 1.3 and 15 MeV on U-233, U-238, and Pu-239, using fission chambers inside a large scintillator tank. The correction for relative variations in the neutron spectra may be uncertain by 0.5%.

KFK Karlsruhe

Pfletschinger is carrying out measurements of Pu-239 to U-235 fission ratios between 30 and 300 keV. Albold reports studies of Doppler broadening on the 6.68 eV resonance in $^{238}UO_2$. He finds that a scattering-law treatment based on a lattice vibrational model for UO_2 agrees well with the data.

CEN, Mol

At the Belgian center, Neve is attempting measurements of the subthreshold fission cross section of Th-232 induced by thermal neutrons, using polycarbonate fission-track detectors. Fabry reports measurements of fission-neutron spectra which agree with the Grundl (LASL) work.

AERE, Harwell

The Pu-239 alpha measurements by Schomberg et al are still being analyzed. The discrepancy between these data and previously accepted values from 1 to 20 keV has been reduced from a factor of 2 to a factor of about 1.5. The latest results are reported in EANDC(UK)100AL. The data of Patrick et al have also been used to derive alpha from 100 eV to 30 keV for Pu-239. Here, they measured eta and assumed $\bar{\nu}$ of 2.864. The largest source of error is in assuming a scattering cross section. The results are somewhat lower than the Schomberg results, but higher than previously assumed alpha values. This work is reported in EANDC(UK)96AL. James reports a multilevel analysis of the Pu-239 fission cross section from 78-88 eV, finding that two fission channels are required for the 0+ spin state. Analysis of higher energy fission cross sections shows structure consistent with Egelstaff fluctuations [JNE 7, 35 (1958)]. James is continuing the measurement of fission cross sections to high precision in the keV region.

If the AWRE data from the Pommard shot do not have sufficient accuracy, AERE will plan to measure alpha for Pu-241 on the Harwell linac.

Studsvik, Sweden

In EANDC(OR)73L, Conde reports $\bar{\nu}$ measurements for spontaneous fission of U-236, finding agreement with a linear relation of 0.11 neutrons/MeV from (U-235 + n). Measurements of $\bar{\nu}$ in neutron induced fission of U-236 are also underway, from threshold to 7 MeV. Accuracies of 1% are projected. A measurement of the fission cross section of Pu-239 from 10 to 100 keV is in progress. Inelastic scattering cross sections are being measured for Th-232 at 0.8 and 1.8 MeV.

A measurement was also reported of the ratio of capture to fission for U-235 and Pu-239 in FRO reactor cores. (This is one of the integral experiments cited as evidence for a high value for alpha of Pu-239 in the low keV region.) The results of this measurement are in agreement with calculation for Pu-239, if one uses the high value of alpha. However, there is also a discrepancy of perhaps 30% for the U-235 ratios.

APPENDIX A

241 TH-NAT DEL 1 MEV- 5 MEV 11 10 PER 15 PER USEFUL 62

Kuchnir (ANL) has data on small angle scattering and polarization below 1.6 MeV.

242 TH-NAT SIN 1 MEV- 4 MEV 11 5 PER 62

Conde reports measurements at Studsvik at 0.8 and 1.8 MeV.

243 TH-NAT NG EV- 2 KEV 1 5 PER OR BETTER IN RI 62

244 TH-NAT NG 2 KEV- 1 MEV 1 5 PER OR BETTER IN RI 66

Asghar et al (AERE), Nuc. Phys. 76, 196 (1966) reported analysis of total and partial cross sections and RPR to 1 keV. Hla Shwe (ANL) has reported RPR for low-energy resonances.

245 TH-NAT GPR EV- 10 MEV 11 10 PER IN SPECTRUM 66

Chrien (BNL) is studying high-energy gammas from the resonances below 100 eV in Th and U.

247 PA-233 NG TH-100 EV 11 10 PER 66

248 PA-233 NG 500 EV- 1 MEV 11 50 PER 66

The Pommard shot was expected to supply data for both these requests. As a result of sample failure, the data are of limited quality, and may not be useful. LASL/INC will hope to repeat this measurement in 1969.

251 U-233 NG EV- 30 EV 1 1/4 PER IN ETA 66

252 U-233 NG 30 EV- 1 KEV 1 1 PER IN ETA 62

253 U-233 NG 1 KEV- 30 KEV 11 2 PER IN ETA 62

Weston's (ORL-RPI) measurements are expected to come closest to meeting these requests.

254 U-233 NG 30 KEV- 3 MEV 11 0.5 PER IN ETA 62

255 U-233 NG 3 MEV- 7 MEV 11 2 PER IN ETA 62

The ORL-RPI measurements may be extended to cover part of the range. Data were obtained from Pommard which may be useful (Bergen, LASL).

256 U-233 RPR TH- 5 KEV 11 SEE COMMENTS 62

ORL-RPI and Pommard are expected to provide the primary input for filling this request.

Sauter (LRL) and Simpson (INC) have scattering data which may be useful.

259 U-233 NF EV- 1 KEV 1 0.5-1.0 PER AT THERMAL 62

260 U-233 NF 1 KEV- 30 KEV 11 2 PER IN ETA 62

Again, ORL-RPI and Pommard may meet these. James at Harwell is measuring in this range. Migneco and Theobald (EURATOM, Geel) are planning measurements to 3 keV.

261 U-233 NUN EV- 1 KEV 1 0.5-1.0 PER 66

262 U-233 NUN 1 KEV- 10 MEV 11 1-3 PER 66

263 U-233 NUN 7 MEV- 14 MEV 11 62

Weinstein (RPI) is working on the problem at lower energies. Euratom (Geel) reports plans to measure to 3 keV. Soleilhac (CEN, Saclay) will measure between 1.3 and 15 MeV.

282 U-235 NG TH- 30 KEV 11 3 PER 62

283 U-235 NG 30 KEV- 150 KEV 11 4 PER IN X-SEC 62

284 U-235 NG 150 KEV- 7 MEV 11 5-10 PER 62

DeSaussure (ORL-RPI) has data at the lower end of the range.

285 U-235 RPR TH- 5 KEV 1 SEE COMMENTS 62

ORL-RPI will provide the primary input. LRL and INC have scattering data which may be useful at the lower energies. Sailor (BNL) will make resonance-spin assignments for lower-energy resonances. Dabbs (CEN, Saclay) is planning to make fission-channel assignments for these resonances, as well.

286 U-235 NF 10 KEV- 8 MEV 1 1 PER 65

287 U-235 NF 1 EV- 10 MEV 11 3 PER 66

288 U-235 NF 10 KEV- 14 MEV 1 1 PER 66

ORL-RPI will cover the lower energies only. Poenitz (ANL) has measured between 30 and 150 keV, normalized to an absolute point at 30 keV. James (AERE) is covering the range below 100 keV. Migneco and Theobald (EURATOM) report measurements to 3 keV. CEN (Saclay) are measuring to 370 keV with a calibrated detector. Hansen (LAS) has reported data below 20 MeV.

289 U-235 ETA TH- 50 KEV 1 SEE COMMENTS 62

Smith (INC) will measure absolutely at thermal and at 2 keV, recommend using ORL-RPI alpha and $\bar{\nu}$ measurements at other energies.

295 U-235 MIS TH 11 SEE COMMENTS 66

DELAYED NEUTRON YIELDS, ABUNDANCES, HALF LIVES, SPECTRUM
Keepin's group (LAS) is still working on this.

296 U-235 MIS TH 11 SEE COMMENTS 66

FISSION NEUTRON SPECTRUM FROM THERMAL INDUCED FISSION
Grundl (LAS) has data from 0.8 to 16 MeV. Fabry (CEN, Mol) has data which agree with Grundl's.

299 U-236 TOT TH- 1 KEV 1 5 PER IN GAMMA-N 62

Carlson (GA) and Harlan (INC) have data being analyzed.

300 U-236 NG TH- 1 KEV 1 10 PER IN GAMMA-GAMMA

301 U-236 NG 1 KEV- 10 MEV 11 20 PER 66

Carlson (GGA) has data being analyzed for RPR at the lower end. Lister (ANL) reports measurements from 0.03 to 1.5 MeV.

302 U-236 NUN 500 KEV- 14 MEV 62

Conde (Studsvik) is measuring to 7 MeV, to 1%.

303 U-237 NF EV- 16 MEV 11 10 PER 63

Cowan (LAS) obtained data on the Pommard shot.

308 U-238 NG 500 EV- 300 KEV 1 5-10 PER 62

309 U-238 NG 300 KEV- 10 MEV 11 3 PER 62

Glass (LAS) reported analysis of Petrel data, which are not consistent with Asghar et al (AERE) results, Nuc. Phys. 85, 305. Poenitz and Lister (ANL) working from 30 to 1500 keV.

310 U-238 GPR 150 EV- 15 MEV 1 30-40 PER ABSOLUTE 66

311 U-238 GPR EV- 10 MEV 11 10 PER IN SPECTRUM 66

Chrien (BNL) is studying lower-energy resonances. Nellis (TNC) has made some survey measurements at 1 MeV neutron energy.

312 U-238 FR 500 KEV- 15 MEV 1 SEE COMMENTS

Stein (LAS) is still working on this below 5 MeV. Hanson (LAS) has reported data to 3 per below 20 MeV.

313 U-238 NUN 500 KEV- 14 MEV 62

Soleilhac (CEN, Saclay) is measuring between 1.3 and 15 MeV.

317 NP-237 NF MEV 11 10 PER 66

Paya (Saclay) has reported data at the lower end; LAS obtained data from Pommard.

318 NP-237 FR KEV- 50 KEV 11 SEE COMMENTS 66

319 NP-237 FR 50 KEV- 500 KEV 1 SEE COMMENTS 66

320 NP-237 FR 500 KEV- 15 MEV 11 SEE COMMENTS 66

Stein (LAS) is still working on this between 1 and 5 MeV.

323 PU-238 NG TH- 1 KEV 1 10 PER 66

324 PU-238 NF 10 KEV- 10 MEV 1 10 PER 62

325 PU-238 NF 10 KEV- 10 MEV 1 10 PER 62

Data from Persimmon (LAS, INC, and AWRE) are still being analyzed. New fission data were also obtained in this region on the Pommard shot (Bowman, LRL). Barton and Koontz (LAS) have data between 1.5 and 3 MeV.

329 PU-238 MIS 100 KEV- 1 MEV 1 5 PER 66

DESTRUCTION CROSS SECTION
LAS/INC/ALD have NF + NG from Persimmon.

334 PU-239 NG 500 EV- 150 KEV 1 4 PER 62

The Schomberg (AERE) measurements of alpha lie a factor of 1.5 to 2 higher than the accepted curve. Patrick's data are also somewhat high. Gwin (ORL-RPI) data are not yet available. AWRE may have some data from Pommard. Smith (INC) will measure at 2 keV.

335 PU-239 NG 150 KEV- 1 MEV 1 3 PER IN ETA 62

336 PU-239 NG 1 MEV- 3 MEV 11 5 PER IN ETA 62

AWRE has data on NF and NX from Pommard.

337 PU-239 RPR TH- 5 KEV 1 10 PER 62

ORL-RPI data will probably provide the input for this. Scattering data and systematics have allowed spin assignments for most resonances. James (AERE) reports a multilevel analysis from 78-88 eV, and a fluctuation analysis in the 1 keV region.

341 PU-239 NF TH- 1 EV 1 1 PER 62

342 PU-239 NF 500 EV- 100 KEV 1 3 PER 62

Measurements at Studsvik will cover range from 10 to 100 keV. ORL-RPI will provide some data at lower energies. AWRE data from Pommard will cover high energy end. James (AERE) has data in this region.

343 PU-239 FR 10 KEV- 15 MEV 1 SEE COMMENTS 66

Pfletschinger (KFK, Karlsruhe) is measuring between 30 and 300 keV.

344 PU-239 NUN 5 MEV- 14 MEV 62

345 PU-239 NUN TH- 10 MEV 1 1-3 PER 66

Weinstein (RPI) data will cover resonance region. Soleilhac (CEN, Saclay) is measuring between 1.3 and 15 MeV.

346 PU-239 ETA TH- 1 EV 1 1 PER DESIRE 0.5 PER 62

347 PU-239 ETA 1 EV-- 10 EV 11 3 PER 62

Smith (INC) is approaching the desired accuracy at 0.025 and 0.06 eV. ORL-RPI data on alpha and $\overline{\nu}$ will overlap the absolute points.

357 PU-240 NG 1 KEV- 3 MEV 11 10 PER 65

358 PU-240 NG 500 EV- 150 KEV 1 5 PER 65

359 PU-240 NG TH-100 EV 1 3 PER 66

360 PU-240 RPR 100 EV- 5 KEV 1 10 PER 65

Petrel data (Byers, LAS) should be good to 10% especially if normalized to EURATOM data. Complete data on Pu-240 at low energy appear to be available. These requests may have been fulfilled.

361 PU-240 ALF 150 KEV- 7 MEV 1 10 PER 62

362 PU-240 ALF 150 KEV- 7 MEV 1 10 PER 62

Petrel data should be good to 10%.

366 PU-241 NG TH- 30 KEV 1 3 PER IN ETA 66

AWRE obtained data from Pommard, but probably not to this accuracy. Smith (INC) has measured eta absolutely at thermal (0.025 and 0.06 eV).

367 PU-241 RPR TH- 400 EV 11 SEE COMMENTS 66

Sauter and Bowman (LRL) have scattering data and resonance spin assignments to 30 eV.

369 PU-241 NF TH- 30 KEV 1 SEE COMMENTS 66

370 PU-241 ETA 400 EV- 7 MEV 1 5 PER 62

AWRE data from Pommard might flesh out the existing data at low energies to fill these requests. Can use systematics for $\overline{\nu}$, and calculate η from $1 + \alpha$ to 5%.

387 CM-243 NF TH- 10 KEV 11 10 PER IN RI 66

On Pommard, obtained data only above 100 keV, LAS will plan to repeat measurement in 1969.

389 CM-244 NF- 10 KEV- 10 MEV 1 10 PER IN RI 66

Fullwood (LAS) reported data from Persimmon over the entire region of interest. Barton and Koontz (LAS) measured FR to U-235 between 1.5 and 3 MeV.

394 CM-245 NF TH- 10 KEV 11 10 PER IN RI 66

Diamond (ANL) reported thermal column results.

398 CM-247 NF TH- 10 KEV 11 20 PER IN RI 66

Diamond (ANL) has reported measurements in a thermal column.

404 CF-252 NG TH- 10 KEV 17 20 PER IN RI 66

Gordon and Weinstock (BNL) report an upper limit of 100 b for RI.

APPENDIX B

Comments on Requests Which are Not Presently Being Actively Pursued

(1) Requests number 275, 276, 279, 280, 304, 330, 331, 333, 356 (DEL and EM from 1 to 14 MeV, for U-235, U-238, Pu-239 and Pu-240). Smith at ANL is planning to do all these with the advanced neutron generator. For these measurements the problem of sorting out scattered from fission neutrons is not too bad with time-of-flight.

(2) Requests number 250, 277, 278, 305, 306, 332, 355 (SIN, 1 MeV to 4 MeV, for U-233, U-235, U-238, Pu-239, and Pu-240). If one measures neutrons, he needs to know accurately the fission spectrum neutrons which constitute a sizable background to the inelastic groups. Smith (ANL) will attempt this. Morgan (TNC) could extend his measurements to fissionable materials and try to sort the gamma radiation from inelastic scattering from the capture, fission, and natural activity of the sample.

(3) Requests number 258, 281, 297, 298, 338 (GPR and radiative capture gamma spectra from U-233, U-235, and Pu-239, thermal to 15 MeV). Again, Morgan (TNC) has worked in this area. Fission-gamma coincidence/anticoincidence, with time-of-flight to sort out scattered neutrons, might give required data at low energies. The big problem is the natural and fission-induced activity of the samples.

(4) Requests number 246, 249, 257, 272, 290, 339, 340, 378 (N2N and N3N for Th-232, Pa-233, U-233, U-234, U-235, Pu-239, and Am-241, from threshold to 15 MeV). Sorting out a boil-off spectrum from a fission product spectrum seems rather difficult. Perhaps one could set up a $\overline{\nu}$ measurement and record both delayed coincidences and anticoincidences with fission events. It appears that in many cases, what is desired is the production cross section of the reaction product. Especially for very active samples such as Pa-233, activation in various reactor spectra might be useful.

(5) Requests number 264, 343, 363, 364, 368 (FR to U-235 for U-233, Pu-239, Pu-240, and Pu-241 to 15 MeV). Barton and Koontz (LAS), and Stein (LAS) could do these.

(6) Requests number 265, 266, 267, 268, 291, 292, 293, 294, 351, 352, 353, 354 (Yield of Xe-135, Cs-137, Sm-149, and Nd-147 from fission of U-233, U-235 and Pu-239 from thermal neutron irradiation). The accuracies required (1-3%) make these look difficult.

(7) Requests number 269, 381, 382, 384, 386, 391, 392, 395, 396, 399, 400, 401 (Total cross sections and RPR of U-234, Am-242, Am-243, Cm-242, Cm-243, Cm-244, Cm-245, Cm-246, Cm-247, Cm-248, Bk-249, Cf-250 to 10 keV). A new technique, tested on Pommard, will give

high-resolution total cross-section measurements with gram-sized samples on nuclear explosions. MTR chopper can cover lower energy region.

(8) Requests number 270, 271, 315, 316, 322, 373, 379, 380, 383, 385, 389, 402, 404, 406 (NG for U-234, Np-237, Np-238, Pu-242, Am-241, Am-253, Cm-242, Cm-244, Cf-251, Cf-252, Cf-253). Nuclear explosions can do these with samples of gram-size or less. Large volume capture tanks not useful because of sample activity in most cases. Activation may be useful for thermal measurements.

(9) Requests number 273, 327, 328, 344, 365, 371, 372, 376, 390, 405 (NUN for U-234, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Cm-244, Cf-252, to 14 MeV). Standard techniques are appropriate for some measurements; others, where the sample is fairly active, might require nuclear explosion sources. A fission neutron detector was utilized successfully by AWRE on Pommard.

(10) Requests number 314, 377 (NP for U-238, Pu-242 at 14 MeV). One might use a combination of absorbers and dE/dx detectors.

(11) Requests number 394, 398, 403 (NF for Cm-245, Cm-247, and Cf-251). Nuclear explosions appear to offer the most promise for resonance energy cross sections. Use spark chambers in a reactor for thermal measurements.

(12) Requests number 393, 397, 407 (ALF for Cm-245, Cm-247, and Es-254). Nuclear explosions will give NG + NF and NF. Obtaining enough material for sample preparation is the problem.

(13) Other, miscellaneous requests.

348, 349. DN, D2N on Pu-239, from threshold to 12 MeV. Perhaps the best way is to look for reaction products Am-240 and Am-239.

350. N-NF on Pu-239, 7-14 MeV. The step at 6 MeV is a measure of this process. One might look for a small, systematic difference in the mass distribution to sort out first- and second-chance fission.

375. ETA for Pu-242, 0.5 to 10 MeV. To 5%, one can use $1 + \alpha$, from a nuclear explosion measurement, and $\overline{\nu}$.