A RADIOCHEMICAL STUDY OF THE REACTIONS OF HEAVY IONS WITH GOLD

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ABSTRACT

Thick gold foils have been bombarded with heavy-ion projectiles at energies above the Coulomb barrier. The radioactive products were identified and their yields measured using gamma-ray spectrometry and an extensive series of computer programs developed for the data analysis. The total mass-yield distribution was extracted from the data using charge-dispersion curves inferred from the experimental results.

One observes a change in the mass-yield distributions corresponding to primarily fusion-fission reactions occurring with the lighter projectiles Ne-20 and Ar-40 and deep-inelastic transfer reactions predominating with heavier Kr-84, Kr-86 and Xe-136 projectiles.

For the deep-inelastic transfer reaction, more mass transfer is seen to occur for a higher incident projectile energy, and the Gaussian distribution of products shows exponential tailing. The preferred direction for mass transfer is from gold to the projectile nucleus. Sequential fission is a likely fate for nuclides beyond the lead shell closure. The "gold finger" is explained as a combination of mass transfer, nucleon

evaporation and sequential fission.

The yields of gold nuclides indicate a superposition of two reaction mechanisms, quasi-elastic and deep-inelastic. The angular momentum involved with each mechanism determines which of two isomeric states is the end product of the nuclear reaction.

Suggestions are offered regarding the possibility of synthesizing super-heavy elements by use of heavy-ion nuclear reactions.

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I. INTRODUCTION

A. Background

Heavy-ion reactions form a rather recently opened field of nuclear studies, and heavy ions provide a tool with capabilities previously unavailable. Heavy-ion projectiles can bring in massive amounts of angular momentum, and much study is going into the role of angular momentum in nuclear reactions and the nuclear response to the angular momentum. High-spin nuclear states are made accessible by the heavy ions, either by Coulomb excitation or by nuclear interactions. The collision of two large collections of nucleons emphasizes the collective and hydrodynamic properties of nuclear matter; one learns more about viscosity, nuclear friction and the coupling of excitation modes of the nucleus. The time scale for heavy-ion reactions can be such that the contact between the target and projectile is interrupted after substantial interaction, but before equilibrium has been achieved. Thus, the situation at some point along the reaction pathway is preserved in the products, and the mechanisms of nuclear reactions are illuminated. The data allows estimates to be made of the rates of charge transfer, energy equilibration and particle transfer.

Nuclear particles have been used to cause the transmutation of nuclides since an early stage of the nuclear age. Accelerated particles were used to produce the first element¹ that had not previously been found in nature (Tc). Virtually none of the elements above uranium in the periodic table are to be found in nature, but

they have been synthesized using nuclear reactions. As one seeks to leap further and further beyond the naturally occurring elements, greater reliance must be placed on using heavy ions to accomplish this aim.

Elements above uranium become, in general, less stable as the atomic number increases because of the increasing Coulomb repulsion. Nuclear theorists have predicted a region of enhanced stability in the neighborhood of $Z \approx 110-114$.²⁻⁴ Nuclear shell structure is responsible for this prediction. The extent of this enhanced stability might be enough that some superheavy elements may have survived in nature to the present time. Many attempts have been made to find evidence for their existence,^{5,6} but nothing conclusive has thus far been published and accepted by the scientific community.

Perhaps science can produce what nature may not have provided. Heavy-ion reactions are prime candidates for furnishing the means to jump from the long-lived or stable target nuclides available to the researcher into the so-called "Island of Stability." Here too, no positive success has been reported,^{6a} but the efforts continue with new combinations of target and projectile, more intense accelerator beams, new methods of chemical isolation for the predicted elements, more sensitive techniques of detection and higher or lower beam energies.

The hope is that one of three nuclear reaction mechanisms will yield the superheavy elements sought. The compound-nucleus mechanism involves the union of the projectile and target nuclei into one excited nucleus that would de-excite by emission of a few nucleons leaving a

nucleus within the Island of Stability. The sum of the target and projectile nucleons must be just slightly larger than what would be appropriate for the superheavy elements. A particular problem for this mechanism is that for the combinations of nuclei available, the resulting compound nucleus is too neutron-deficient, and the residue surviving after nucleon evaporation is even further from the line of stability. In the fusion-fission mechanism, the massive target and projectile nuclei fuse together to form one "amalgamated" system, not necessarily a compound nucleus, and then fission into a symmetric distribution of products typical of high-energy fission. Hopefully, the distribution would extend into the region of the superheavy elements. The third approach requires the transfer of a sufficient number of nucleons from one nucleus to the second to give a product with the proper number of protons and neutrons.

All three possibilities suffer from several limitations. The projectile must be given enough kinetic energy to overcome any energy barriers; thus, the resulting excitation energy in the products is quite high. The nuclides with large atomic numbers have less resistance to fission because of the increasing coulomb repulsion. Coupling the high excitation energy with a low fission barrier severely reduces the survival ability of any high- Z product. This is especially true because the probability to survive is dependent on excitation energy and barrier height in an exponential way. Also, the neutron-to-proton ratio of the targets and projectiles that can be used creates a low probability of arriving at an adequately high neutron number. This problem is aggravated by further neutron loss

likely to occur in the de-excitation of the products.

Figure 1 illustrates the results⁷ obtained from a radiochemical study of the nuclear reaction $605\text{-MeV } ^{84}\text{Kr} + ^{238}\text{U}$. The experimental technique used was similar to the ones to be described in the experimental section of this report. The individual nuclidic yields were used to obtain the integrated mass-yield data of figure 1c. The total curve was factored into components corresponding to the various reaction mechanisms believed to be operative in the interaction above the coulomb barrier of ^{84}Kr and ^{238}U .

The component labeled A results from the fusion-fission reaction mentioned earlier. The target and projectile fuse together to form a composite system that maintains little memory of its origins. It is uncertain whether or not it would be reasonable to call the composite system a compound nucleus because of the short time the system is believed to survive before fissioning. The fission is symmetric in mass distribution, as is typical for high-energy fission reactions, and the products are symmetrically distributed in space about the fission's origin. The fusion-fission mechanism is one prime candidate for production of superheavy elements,⁸ and a measurement of its characteristics may certainly help predict its likelihood for success.

Components E and F, the so-called "rabbit ears," form narrow distributions just around the target and projectile mass and atomic numbers. Quasi-elastic transfer reactions give rise to these fractions. The kinetic energy of the resulting fragments has been found to be slightly less than the energy brought into the center-of-mass coordinate system by the target and projectile nuclei. This reaction mechanism

is described as a glancing collision occurring as the projectile brushes past the target at the largest impact parameters, with the exchange of a few nucleons perhaps taking place and with very little kinetic energy converted into internal modes of excitation. The cross section has been found to be concentrated in the neighborhood of the grazing angle. One would expect that the quasi-elastic cross sections for the target and projectile should balance, but it was found that the target cross section is less than expected.

This apparent deficit can be rectified by adding together the cross sections for component F and one half of component B. The products comprising component B are similar to those coming from the moderately low-energy (~ 30 MeV) fission of ^{238}U . The nuclides are neutron rich, and their yield distribution is asymmetric with an apparently moderate peak-to-valley ratio. That a uranium nucleus should fission after undergoing the small excitation involved in the quasi-elastic mechanism is not surprising in light of its low fission barrier (6.8 MeV). Having a high neutron-to-proton ratio, the U-238 nucleus yields neutron-rich fission products that do not evaporate a large number of neutrons because of the small amount of internal excitation.

One of the surprises coming out of heavy-ion reactions research is the previously unexpected finding⁹ that a substantial fraction of the cross section goes into what has been variously termed quasi-fission, deep-inelastic reactions and relaxed phenomena. This reaction mechanism is characterized¹⁰⁻¹² by fragment kinetic energies being close to that of Coulomb repulsion, by fragment masses close to that of both the target and the projectile, by focusing into an angular region around and less

than the grazing angle, and by containing the increase in cross section obtained by raising the projectile energy. In the accompanying figure, component C represents the deep-inelastic reaction products that can be identified with the projectile Kr-54, but a similar distribution is not present about the target U-238. Rather, the internal excitation energy present causes the fission of these products which can be seen in the distribution as component D. This broad symmetric fission product distribution indicates that a substantially high degree of internal excitation existed in the pre-fission nuclei.

Component G could not be attributed to any reaction mechanism, and its origin was a puzzlement. This component is colloquially named the "gold finger."

The yields and factorization obtained in the reaction of Xe-136 with U-238¹³ were very similar to the krypton example.

B. Why Choose Gold As A Target

It was decided to perform an extensive radiochemical study of the reaction products arising from the interactions of heavy ions with gold. Gold was chosen because of several advantages it offers and because it is suited to answering several important questions being asked.

Stable gold is a mono-isotopic element with mass number 197. This provides only one target origin when one considers the accounting of protons and neutrons going into the nuclear reaction and those found in the products; having to average over several isotopes of a target element results in blurred conclusions. Gold is readily available in high purity and in various thicknesses. It is an outstanding conductor of heat,

so that target cooling is facilitated, but its melting point (1063°C) is, unfortunately, not very high.

The fission barrier in the neighborhood of stable gold is around 22 MeV.¹⁴ This is substantially higher than the value of 6 MeV for the region of uranium. This difference should tremendously reduce or eliminate losses by fission of products made from the gold target. But the gold nucleus, with its 197 nucleons, still acts as a massive nucleus and so simulates many properties of the earlier studied uranium nucleus.^{7,13,15}

Gold is located slightly below the doubly-magic lead region, and it might be possible to observe the results of shell effects in this highly favorable area.

As seen in table 16, nuclear isomerism occurs for many gold isotopes, and several of the high-energy isomers are accessible to gamma-ray detection following chemical isolation. A distinctive property of the high-energy isomeric states is their high nuclear spin relative to the ground state. An examination of the yields of the low- and high-spin states may show the influence of angular momentum on the nuclear reactions.

C. Other Heavy-ion Experiments Performed With Gold

Several studies of heavy-ion reactions with gold as the target nucleus have been performed in the past. One of the earliest was the thesis work¹⁶ of Blann, who conducted a radiochemical examination of the yields and charge distributions resulting from the fission of gold with 112-MeV C-12 ions. More recent work with heavier ions has been

performed using accelerators at Orsay (France),¹⁷⁻²¹ Dubna (U.S.S.R.),²²⁻²³ Manchester (United Kingdom),²⁴ Darmstadt (German Federal Republic)²⁵ and Berkeley (U.S.A.).²⁶⁻³³ Additional heavy-ion experimental research has been carried out at the above accelerator laboratories with targets other than gold, and many of the results and conclusions so obtained are certainly of great value when examining the interactions of heavy ions with gold.

A number of publications have been produced by the Berkeley research group led by L. G. Moretto. They have used on-line particle detection techniques to study heavy-ion reactions, including 288-MeV Ar-40,²⁶ 340-MeV Ar-40,²⁶ 620-MeV Kr-86,^{27,28} and 980-MeV Xe-136²⁹ bombardments of thin gold targets. They determined differential cross sections as a function of atomic number and exit-channel kinetic energy. They, as well as others, have developed a nuclear mass diffusion model that rather successfully reproduces the angular distribution of deep-inelastic reaction products also as a function of atomic number.³⁴ Side peaking originally observed for quasi-fission products was related to the forward peaking found for other reactions, and a determining parameter is the ratio of the center-of-mass bombarding energy to the Coulomb energy. It is thought that the angle of product emission is related to the length of time the target and projectile nuclei are in contact with each other, are rotating about each other and are able to exchange nucleons; and higher projectile energy permits longer contact time. Some of the most recent work included the finding of secondary fission of some gold-type products as a result of the deep-inelastic reactions

of 980-MeV Xe-136 + Au-197. The success of this experimental program is very much due to the development of a gas-ionization detector that permits fragment atomic number identification even beyond $Z = 60$.³⁵

A group of physicists using the French heavy-ion facility ALICE at Orsay have also conducted experiments using gold as the target material, and many of their results parallel those just mentioned. They were able to reproduce in the reaction 220-MeV Ar-40 + Au-197 the side peaking observed when using heavier projectiles.³⁶ In addition, the tendency for the most probable angle of emission to move forward with increasing projectile energy was tested by using both 365- and 443-MeV Cu-63 ions to bombard gold.¹⁸ They have also used a random-walk diffusion model to explain their results.²⁰ They reported¹⁹ on sequential fission occurring in the bombardment of gold with 443-MeV Cu-63. They measured¹⁸ the gamma-ray multiplicity accompanying the reactions of 443-MeV Cu-63 with Au-197 and found the average multiplicity to be rather high for deep-inelastic reactions (identified by measuring in coincidence the light product kinetic energy). For the angles at which they detected the outgoing fragments (both 35° and 49° in the lab), they deduced that gamma rays carried off an average of about 45h and that 10% of the de-excitation involved a statistical cascade of E1 transitions and the remaining 90% consisting of E2 transitions of the yrast cascade. The kinetic energy observed for the deep-inelastic exit channel was virtually identical for the two bombarding energies 365 MeV and 443 MeV.²¹ More cross section was found at the higher bombarding energy for products that may result from the fusion-fission

mechanism, but it was recognized that these yields could also come from increased diffusion.

Experiments conducted at Manchester and the University of Marburg entailed the bombardment of thick gold targets with 540-MeV Fe-56 nuclei and radiochemical measurement of the products. In a preliminary report,²⁴ a qualitative description of the mass-yield distribution is presented. The distribution includes "rabbit ear" quasi-elastic, deep-inelastic, fusion-fission, and perhaps secondary fission components.

A report²⁵ on a set of early experiments performed using the UNILAC facility concerned the relatively low-energy bombardment (5.9 MeV per atomic mass unit) of thick gold targets with various xenon isotopes. The study found no evidence for symmetric mass division from fusion-fission; quasi-elastic and deep-inelastic reactions were the only mechanisms found operative. The yields for gold isotopes showed two components present.

From the Joint Institute for Nuclear Research at Dubna have come two papers^{22,23} that include discussions on the products from the heavy-ion bombardment of thick gold targets. The projectiles ranged from C-12 to Xe-136. These reports include only one distribution to describe the yields of Au isotopes. Asymmetric fission is suggested as responsible for production of nuclides not close to the target, but it is more likely that the deep-inelastic mechanism is the source for these nuclides.

One study³⁰ was conducted at Berkeley on the products of Ar-40 + Au-197 with the projectile energy slightly above the Coulomb

barrier. Very thin target foils, small solid angles for product collection, and the use of gamma-ray spectrometry to measure cross sections limited the sensitivity of the experiments; however, the experimenters were most interested in products resulting from few-nucleon transfers, and these products are found in great profusion. They attempted to use semi-classical transfer theory to reproduce their results and found that it worked close to the barrier in the backward direction, but not elsewhere.

Some of the material to be covered here has already received mention in various earlier reports.³¹⁻³³

Of course, added insight into the mechanisms of heavy-ion reactions can be gained from the many other experiments conducted with other target materials.

II. EXPERIMENTAL METHODS

The experimental methods used are described in this section. Each experiment can be viewed as consisting of four phases:

- 1) gold foil bombardment,
- 2) target processing,
- 3) gamma-ray spectral measurements, and
- 4) data analysis.

These will be treated in the following sections. They are usually discussed in general terms so that the reader may gain a sense of the experimental goals and the means used to achieve them. The methods evolved as the work progressed, and improvements were made along the way. The details presented here usually represent the best methods used (in the judgment of the author).

Table 1 contains the details of the accelerator bombardments. The sample identification contains first the symbol of the element or element group isolated in the chemical processing of the gold foil, second the research group bombardment number that is assigned serially, and last the target material (in these experiments always AU).

The method of data analysis is explained in great detail because it is believed that this is a powerful tool that allows disentanglement of complex spectra and the extraction of meaningful results.

Table 1. Bombardment Details

Experiment	Projectile	Lab Energy	Length of Bombardment	Typical Beam Intensity
26AU	Ar-40	336 MeV	228 minutes	1000 nA (D.C.)
29AU	Ar-40	336	171	1000
33AU	Ar-40	336	121	1000
38AU	Ar-40	336	152	900
40AU	Ar-40	336	142	1000
45AU	Kr-84	705	150	200
50AU	Kr-84	705	300	300
53AU	Ne-20	252	2400	100
54AU	Ne-20	252	22	95
57AU	Kr-86	730	24	130
61AU	Kr-86	620	2715	60
63AU	Ar-40	336	240	200
64AU	Kr-86	730	120	500
68AU	Kr-84	705	275	250
95AU	Xe-136	1140	160	600
96AU	Xe-136	1140	25	150

A. Gold Foil Bombardments

1. SuperHILAC

Most of the experiments were conducted using the Lawrence Berkeley Laboratory Super Heavy Ion Linear Accelerator (SuperHILAC).³⁷ Gold foils (99.95% pure)³⁸ 0.051 mm thick usually served as the target. This thickness is adequate to contain all the primary nuclear reactions taking place above the Coulomb barrier and to stop all the reaction products except for a very small number that escape out the front side. An additional gold foil followed the target to isolate the target packet from other materials and to provide greater structural integrity for the target. All gold foils were cleaned in an acetone bath before use. Consistent yields for Na-24 from different experiments using the same projectile indicates that the effects of common surface contaminants were kept to a tolerable minimum. The target and backing foils were clamped in a target holder that allowed 1) a spray of water directed onto the back side of the backing foil to reduce heating problems, 2) collimation of the beam to 11 mm diameter with the collimator electrically isolated from the target, 3) collection of the beam incident on the target to enable determination of the beam current and integrated dose. Regarding the last point, two 500-G rare-earth magnets were included to steer secondary electrons into the target if they originated there or away from the target if the electrons were emitted elsewhere. The target foils were typically 19 mm x 19 mm square, but unexposed portions of the foils were trimmed away following the irradiation unless it was necessary to start

measurements as soon as possible. The target holder was positioned just beyond the post-stripper exit of the SuperHILAC. The energy spectrum of the beam was measured using a solid-state crystal, and it was found that up to 20% of the beam might have an energy below the maximum desired. Figure 2 shows a typical calibration spectrum. The target position does not allow any bending of the beam after it exits the accelerator, and a major worry has been the possible contamination of the beam with lower energy projectiles or with a different projectile. The SuperHILAC has been recently altered to allow the acceleration of two projectiles in separate pulses of the machine's operating cycle. To test for possible contamination by the ^{20}Ne beam that was being run in addition to the desired ^{84}Kr beam, the krypton beam was attenuated by a factor of approximately ten billion and then found to be about equal to the neon beam entering the target area. The disadvantages of the above described target position were outweighed by considerations of the greater beam current available at this location.

To check on the possible interference by products produced by secondary particles (e.g., slow neutrons, fast protons), the radio-activity induced in the backing foil was measured and compared with the activity found in the target foil. The nuclides ^{195}Au , ^{196}Au , $^{197\text{m}}\text{Hg}$, and ^{198}Au were identified in the backing foil two days after the end of the bombardment. Their presence relative to that in the target foil for the identical isotopes was less than 2% although the backing foil was five times thicker. As a result, the effects of secondary particles were not considered in evaluating the data.

In some cases the irradiated target foils were chemically processed as described below. In the remaining cases, the foil was centered on an aluminum counting card and secured with a covering of cellophane tape. When the gamma-ray measurements had to begin as quickly as possible after the end of the bombardment, the delay involved ranged from five to ten minutes. This enabled preparation of decay curves for nuclides with half lives as short as four minutes in the most favorable case.

One experiment (labeled 61AU) was performed parasitically at the SuperHILAC at the end of beam line 78. A gold foil 0.25 mm thick and 25.4 mm square was placed inside a Faraday cup for an irradiation with 620-MeV ^{86}Kr . Thin foil targets, degrading the beam prior to interaction with the thick gold target, reduced the beam energy by less than ten MeV, 39 and the beam will be here treated as having the nominal energy of 620 MeV. The beam intensity varied within the range 20-80 nA (D.C.).

During the course of several experiments, the projectile beam was apparently too finely focused upon the target and "drilled" a small hole in the target foil. Never was the integrity of the backing foil threatened. Such a target was still usable, but the yields determined therefrom had to be normalized using results obtained in another experiment.

During most experiments an attempt was made to keep the beam intensity nearly constant (~20%) so that calculations of cross-sections for relatively short-lived nuclides would be simplified and more precise.

2. Cyclotron

Two experiments involving the bombardment of gold target foils with a ^{20}Ne beam were carried out at the 224-cm sector-focused cyclotron⁴⁰ located at Lawrence Berkeley Laboratory. In each experiment the target was a gold foil 0.25-mm thick. The ^{20}Ne beam was tuned to an energy of 252 MeV for the experiments.

The first experiment was performed in a parasitic mode such that the beam first passed through several thin foils before striking the gold target located about one meter further downstream. The energy lost in the thin foils amounted to less than 2 MeV³⁹ and has been ignored in this analysis. The target was contained within a Faraday cup located in Cave 1, but the readings from this cup were not being taken continuously during the entire experiment. To correct for this lack of a good measurement of the total beam dose, the results obtained here were normalized to those obtained in the second experiment. The length of bombardment was approximately $1\frac{1}{2}$ days, and the beam current averaged 100nA (D.C.). The target foil was removed from the Faraday cup 105 minutes after the end of the bombardment. A visual examination of the foil showed no visible damage. An autoradiograph of the foil was prepared using Polaroid Type 57 film in order that the area struck by the beam could be located and excess target material cut away. Figure 3 illustrates the size of the original target foil and the portion that was examined for activities. Removing a substantial fraction of the original material reduces the interference caused by products arising from secondary-particle-induced reactions. Gamma-ray

measurements commenced four hours after the end of the bombardment.

The second experiment was intended to emphasize detection of short-lived activities ($t_{1/2}$ = 5 minutes or longer) and to enable a precise measurement of the beam current and integrated dose. The target for this experiment was located at the FCS1 position that ordinarily contains a Faraday cup. The beam was steered to the target position by aiming it at a crystal that was initially placed in the target position and that was made visible to the operators by use of a television camera. The beam intensity was maintained within the range 80-110 nA (D.C.), and the average beam current was 95 nA. The bombardment lasted 22 minutes, and gamma-ray measurements started 8 minutes after the end of the bombardment.

Table 1 contains data on the particle bombardments conducted.

B. Processing of Targets Following Bombardment

1. Chemical Processing

Several experiments involved the preparation of samples containing one element or a particular group of elements. Such samples allow greater sensitivity for detecting a nuclide, provide an additional piece of information to enable identification of the nuclide responsible for an observed activity and may help to better determine the independent yield of the nuclide in the nuclear reaction.

The target foil had scribed into it the outline of the area exposed to the projectile beam. Following the bombardment, as much excess target material as could have been safely and expeditiously

removed was cut away. The remaining foil was dissolved in aqua regia ($2\text{HCl}:1\text{HNO}_3$), although in some cases HBr was used in place of HCl as part of the group separation procedure⁴¹ that depends on the tendency for softly acidic ions to form complexes (see below).

The first chemical step involved removing the massive amount of gold present in the foil. An attempt was made to extract gold with ethyl acetate, which is well known⁴² to be rather specific for removing gold from an aqueous phase. However, the strongly acidic and oxidizing conditions in the aqua regia apparently led to hydrolysis of the ethyl acetate and loss of immiscibility. An alternative that worked involved using ethyl ether as the extractant for the first two stages of gold removal from the aqueous medium and ethyl acetate for the third and fourth extractions. The third extraction usually resulted in an organic phase without a visible gold color.

Table 2 catalogues the samples prepared.

a. Procedure to Prepare Au, Tl, Hg and La Samples. A 0.051 mm gold foil was bombarded with ^{86}Kr at the SuperHILAC and transported by truck to the chemistry laboratory. The foil was cut to trim away most of the unexposed portion of the gold, and the remainder was placed in a beaker containing 3 mg Hg carrier, 2 mg Tl carrier. Aqua regia was freshly prepared in the beaker by adding two parts HCl to one part HNO_3 , and the beaker was heated with a flame to accelerate the dissolution. Care had to be taken to prevent the solution from spattering at this stage, and following the dissolution the sample was transferred to a 3-ml centrifuge cone. Distilled water was used to

Table 2. Samples Prepared

Experiment	Projectile	Samples
26AU	Ar-40	I26AU, DI26AU, SH26AU, PB26AU, U26AU, LA26AU, TH26AU, FI26AU
29AU	Ar-40	PB29AU
33AU	Ar-40	AU33AU, HG33AU
38AU	Ar-40	OS38AU
40AU	Ar-40	PT40AU
45AU	Kr-84	OS45AU, I45AU, PT45AU
50AU	Kr-84	DI50AU, SH50AU, PB50AU, U50AU, LA50AU, TH50AU, AU50AU
53AU	Ne-20	53AU
54AU	Ne-20	54AU
57AU	Kr-86	57AU
61AU	Kr-86	61AU
63AU	Ar-40	63AU
64AU	Kr-86	AU64AU, TL64AU, HG64AU, LA64AU
68AU	Kr-84	68AU
95AU	Xe-136	95AU
96AU	Xe-136	96AU

complete the transfer and approximately double the volume, so that the HCl concentration was in the neighborhood of 6M. This was followed by 1 ml of diethyl ether, which will extract both Au and Tl.⁴² The solvent had been pre-equilibrated prior to having been used in the experiment. A spitzer and syringe device was used to bring the two phases into greater contact with each other. The extraction took place both in the spitzer as the two solutions were being drawn into it and in the centrifuge cone to which the liquids were returned. Following four cycles of mixing, the aqueous phase was withdrawn and added to 1 ml of pre-conditioned ether contained in the next centrifuge cone. The mixing process was repeated for this stage and for the third and fourth stages of the Au and Tl extraction from the aqueous phase.

Only the first two diethyl ether fractions were combined and processed to isolate Au and Tl samples because most of these two elements were contained in these fractions. The combined organic fraction was washed twice with 2 ml portions of 6M HCl to reduce the amount of impurities. The diethyl ether was evaporated from a beaker on a hot plate, but 1 ml of hot, distilled water and two drops nitric acid were added so that the sample never went dry. SO₂ was bubbled through the acid solution to reduce gold to the metal⁴³ and thallium to Tl(I).⁴⁴ The metal particles were filtered out by a glass fiber filter paper, and the sample was washed with water and ethanol, dried under a heat lamp and mounted for counting as sample AU64AU. The solution, still containing thallium in the +1 state, was made basic by adding ammonium hydroxide until pH paper indicated alkaline conditions.

Then a concentrated solution of sodium chromate was added, and the solution was heated on a hot plate to encourage a purer precipitation of thalious chromate (Tl_2CrO_4). The solution containing the precipitate was filtered using glass fiber filter paper, and the paper was washed, dried and mounted as sample TL64AU.

Attention is returned to the aqueous phase, from which has been removed the Au and Tl, to see how the mercury sample HG64AU was prepared. The aqueous fraction was reduced in volume by heating on a hot plate, and then the volume was tripled by adding distilled water so that the solution became 2M in HCl. This solution was transferred to a centrifuge cone containing 2 ml of ethyl acetate in order to extract mercuric ion. The two immiscible liquids were mixed as described above for the case of the ether extraction of gold and thallium. The aqueous layer was removed from the cone using the spitzer, and the remaining ethyl acetate was twice washed with 1.5M HCl. To the ethyl acetate was finally added water that had been saturated with H_2S just prior to the commencement of the experiment. The resulting sulfide precipitate was filtered out of the solution, and the glass fiber filter paper was washed, dried and prepared for the gamma-ray measurements.

A 40-ml polycarbonate plastic centrifuge cone had been prepared containing 11 mg of lanthanum carrier. The aqueous phase, having been removed from the ethyl acetate during the preparation of the mercury sample previously described, was added to the cone, and this was followed by several drops of 48% hydrofluoric acid. The lanthanum

fluoride precipitate was centrifuged down, the supernate was discarded, and the precipitate was washed once. To dissolve the precipitate, one drop of hot HNO_3 and a sufficient amount of a saturated HBO_3 solution were added. Next, a saturated ammonium oxalate solution was added to form a new precipitate. This was filtered out, washed, dried and prepared for counting as sample LA64AU.

Table 3 indicates the length of time necessary to carry out this chemistry, and figure 4 portrays the steps of this process.

b. X-ray Qualitative Analysis. Figures 5-8 show X-ray spectra that were taken of the four samples to check on the chemical procedures and to learn something about the relative yields of products made in the nuclear reaction. The spectra were collected about four hours after the end of the bombardment, and the time required for the data collection was only ten minutes for each spectrum. A qualitative examination of the spectra provides a check on the chemistry performed.

In the spectrum from sample AU64AU, one sees mostly X-rays corresponding to the elements Au and Pt and less so for Hg and Ir. This shows that the sample contained gold isotopes undergoing electron capture decay producing Pt X-rays and that some gold isotopes were so neutron deficient that the decay chain continued with further decay to iridium isotopes of mass number 191 and/or 189. The low intensity of Hg X-rays stems from the long half lives and correspondingly small specific activities of the precursors and also the β^- decay involved that does not of itself create K-shell electron vacancies. The large abundance of gold X-rays is mostly a result of fluorescence.

Table 3. Time to Prepare Samples of Experiment 64AU.

End of bombardment	2100
Foil dissolution	2118
Extract AU and TL	2125
Extract HG	2143
Precipitate LA	2155
Count AU64AU	2145
Count HG64AU	2209
Count LA64AU	2212
Count TL64AU	2220

The TL64AU spectrum contains X-rays of Hg, Au and less Tl and Pt. This confirms the quality of the sample chemistry. Thallium isotopes of mass 194 and lighter are present to give rise to the platinum X-rays.

The mercury sample HG64AU shows presence of Hg, Au, Pt and Ir X-rays with lesser amounts of Sn, In and Re. This would suggest that this sample is somewhat contaminated, but an examination of the gamma-ray identifications indicates that this contamination is minimal. As for the previous cases, very neutron-deficient isotopes seem to be present.

The last sample prepared in experiment 64AU was labeled LA64AU. This sample had been expected to contain the entire group of lanthanide elements along with elements with similar chemical properties. The X-ray contains peaks corresponding to the lanthanides along with the daughter barium. Cesium is not strongly indicated, but this could be due to the large number of stable or long-lived isotopes found in the case of barium. Similarly, the X-rays of neodymium, promethium, samarium and europium appear absent; in this case also the nuclear properties of the parents (promethium, samarium, europium and gadolinium) are such as to minimize the number of X-rays emitted. As shown in figure 9, ⁵⁶ half lives for isotopes of these elements are either very long or so short as to preclude detecting a significant number of decays. In a few cases (¹⁵⁰Pm, ¹⁵⁶Sm, ¹⁵⁰Eu, ¹⁵⁷Eu, ¹⁵⁹Gd) the half lives are adequately long, but the decay mode is β^- emission (which reduces the probability for X-ray production), and the production of neutron-rich nuclides seems to be disfavored. Both lead fluoride and lead oxalate are insoluble, so it is not surprising that

Pb, Tl, Hg and Au X-rays are present. Tracer hafnium is carried in rare earth precipitations; hafnium is probably responsible for the lutetium X-rays. Yttrium and strontium X-rays are seen, but the very low energy scandium X-rays are lost.

c. Lead Chemistry. When it was desired to prepare a sample containing only lead, the following chemistry was employed. After extracting most of the gold with ether and ethyl acetate, the remaining aqueous solution was evaporated to near dryness. A small amount of 1.5 M HCl was used to load the sample onto a 2 mm x 5 cm Dowex 1X8 anion-exchange chromatographic column. Three free column volumes of 1.5 M HCl was used to remove most unwanted activities, but the lead stuck to the column. The lead was eluted with three free column volumes of 8 M HCl. The volume was reduced by heating, and then the solution was adjusted to pH 5 using an acetic acid-acetate buffer; 40 mg of lead carrier was added to prepare for the precipitation. The solution was heated to boiling, and sodium chromate added. The precipitate was digested for ten minutes before being filtered, washed with water, washed with 50% ethanol, dried under a heat lamp and mounted on an aluminum card with cellophane tape for gamma-ray counting.

d. Osmium Chemistry. Osmium has the useful property of being easily oxidized to OsO_4 , which is a volatile compound. To prepare osmium samples simply and rapidly, the target gold foils were added to a flask containing concentrated hydrochloric acid and osmium carrier. Concentrated nitric acid, when added to the flask, produced aqua regia to dissolve the gold and oxidize any osmium. Heating the flask helped

to dissolve the foil and to distill over the OsO_4 into a trap containing 40 ml of carbon tetrachloride. The carbon tetrachloride containing the osmium was washed with 20 ml of 2M HCl. Finally, the CCl_4 fraction was added to hot water saturated with hydrogen sulfide and containing one drop of HCl. The osmium tetrasulfide was filtered out, washed, dried and prepared for counting.

e. Halogen Chemistry. The halogens form a group of volatile elements, and their isolation can be coupled with the preparation of an osmium sample as described above. Bromine and iodine carriers were included in the flask used for dissolving the target foil. The halogens distilled over into the CCl_4 trap and were caught there. The halides were subsequently isolated by adding an aqueous phase above the CCl_4 and bubbling through SO_2 gas to bring about reduction and extraction. The osmium remained in the organic phase. The halides were precipitated by adding silver nitrate, and the silver halides were filtered out on glass fiber paper.

f. Platinum Metals. The above separation of volatile elements from the target foil allowed further chemical processing of the dissolved target solution. In the particular experiment described, a sample containing the platinum metals was prepared. Most of the target mass was initially removed by making the solution 2M in HCl and performing an extraction with ether and ethyl acetate. The aqueous solution was taken to near dryness and then taken up in 8M HCl for loading onto a 2 mm x 5 cm Dowex 50X4 cation-exchange chromatographic column. Two column volumes of 8M HCl was run through the column at the rate of one

drop every three seconds to elute the noble metals. The solution was again taken to near dryness and this time taken up in 0.1M HCl for running through a second cation-exchange column with two free column volumes of 0.1M HCl elutriant. At this point platinum carrier was added, and then silver nitrate was added to precipitate the halides and allow their removal. The platinum metals were precipitated by the use of hydrogen sulfide, and the precipitate was filtered, washed, dried and prepared for counting. This sample contained the elements platinum, iridium, rhodium and ruthenium.

g. Group Separation Chemistry. On several occasions it was desirable to use a group separation scheme based on one already described in the literature.⁴¹ The gold target foil was placed in a small flask (figure 10) for the dissolution. Prior to insertion of the radioactive target, the flask had been prepared by addition of iodine carrier and a substantial quantity of concentrated hydrobromic acid. After the target foil had been inserted, concentrated nitric acid was injected to form the bromine analog of aqua regia; bromide was favored over chloride for the later cation-exchange chromatography separations, which was based on the tendency of ions to form complexes with more polarizable ligands. Two fractions of volatile elements were isolated by trapping in CCl_4 the halogens and in water the elements forming volatile bromides. The halogens were reduced with SO_2 and extracted into water. They were precipitated as silver halides by adding an excess of silver nitrate. The volatile bromides were precipitated as sulfides after adding arsenic and mercury carriers. Both precipitates

were filtered using glass fiber filter paper, washed with water and with 50% ethanol, dried under a heat lamp and taped to an aluminum counting card. The remaining material was dissolved in 6M HCl to allow extraction of gold and thallium into ethyl acetate several times so that the remaining material would not exceed the capacity of the following cation-exchange column. After the extractions, the solution was taken to dryness and then taken up in a small volume of 0.1M HBr containing enough added Br_2 to give the solution a slightly red tinge; the presence of bromine insured that various ions would remain in the oxidized form. The solution containing the mixture of activities was loaded onto a 5 mm $\times$ 5 cm ion-exchange column made from Dowex 50X8 (200-400 mesh) cation resin. A thermostatted heating block supporting the column maintained the temperature at approximately 60°C to improve the exchange kinetics. The first fraction (labeled SHE) was eluted with 2 ml (four free column volumes) of 0.1M HBr containing a trace of bromine as noted above. The next fraction (PB) came off in 3 ml (or six free column volumes) 0.65M HBr and a bit of Br_2 . The U fraction was eluted with 2.5 ml 2M HCl, and the LA fraction followed in 4.5 ml of 6M HCl. The TH fraction required 2.5 ml of 0.5M oxalic acid to strip it off the column. (It was noticed that some elements were split between the LA and TH fractions, and it would be advisable in the future to elute with additional 6M HCl.) Each collected fraction was first evaporated down to reduce the volume to an amount as small as manageable, and then the remaining solution was transferred to a 15 mm round microscope glass cover slip for the final evaporation. The

beaker that had contained the eluant was washed out several times to insure that virtually all the activity was transferred to the cover slip. The cover slip was heated on a hot plate to accelerate the evaporation. The cover slip was taped to an aluminum card to enable gamma-ray spectrometry of the sample.

This separation scheme is outlined in figure 11.

2. Gamma-ray Spectrometry Without Chemistry

For each bombarding particle and energy, at least one experiment was performed in which no chemical processing of the gold target was conducted. In some cases the gold foil was placed as quickly as possible in front of the Ge(Li) gamma-ray detector. If time permitted, excess gold not struck by the accelerator beam was cut away.

This method of measurement offered several advantages:

- 1) Measurements could commence within several minutes following the cessation of the target bombardment so that short-lived activities could be observed;
- 2) The yield for each nuclide is nearly 100%, so long as the target did not overheat;
- 3) Determination of at least one isotopic cross section allowed calculation of chemical yield for all the element's isotopes measured in a chemistry experiment;
- 4) Some elements (Ta, W, noble gases), difficult to isolate within the chemistry schemes, posed no problem using this technique; and,

- 5) One such experiment provided a wealth of data surveying virtually the entire range of accessible mass numbers.

The most desirable method was to conduct two experiments for each bombarding particle and energy. One experiment required relatively little accelerator time (<30 minutes) so as to enhance the observation of short-lived nuclides by minimizing saturation effects and reducing spectrum background. The projectile beam had to be held as constant as possible to allow more precise calculation of the saturation factor used in determining the yields of nuclides.

The second experiment was for as long a duration as could be arranged. The primary aim was to achieve the maximum beam dose possible within the limits of accelerator capability and target integrity. Typically, such an experiment might have run for up to eight hours. An alternative was to conduct this experiment parasitically during up to even forty hours of another experimenter's beam time. Gamma-ray spectrometry was not begun until several hours following the end of the bombardment. Such samples yielded results for the long-lived nuclides. The two sets of results from a pair of experiments were normalized to produce consistency by comparing numbers for nuclides observed in both experiments.

A typical spectrum is given in figure 12.

C. Gamma-ray Measurements

1. Counting Strategy

A system had to be developed to determine for how long each gamma-ray measurement should be conducted. The following considerations were applied. The length of each count should not exceed one half life for any of the activities of interest so that the mid point of the counting period can be used as the time of the measurement; this will result in an error of less than 2%.⁴⁵ The length of each count should be maximized in order that the peak-to-background ratio be increased and the peak shape be less subject to fluctuations in count rate. The number of measurements should be reduced whenever possible without sacrificing the quality of the data so as to reduce the amount of data analysis necessary following the data collection. If two or more sample are completing for counting time on one gamma-ray measuring system, the sample(s) having the more complex gamma-ray spectra should be favored. It was noted during the data analysis that no more useful information was collected after about six half lives of any activity; the few nuclides visible beyond the time period of six decay half lives had already been well defined by earlier measurements. Of course, in cases of transient or secular equilibrium, the half life refers to the ancestor, as does most of the information obtained.

In light of the above principles, the following approach to counting was developed. A cycle of three counts of identical length was made for a sample and then the counting period was doubled for the next three measurements. Adding up all earlier counting time with three

made at, for instance, one hour each yields a total counting time of about six hours following the start of the measurement period, or six one-hour half lives. This total time is far from exact because it does not include the dead time for processing signals, the transit time between the end of irradiation and the commencement of counting, or the fact that only three counts were made in the first cycle without any preceding counting time. But this still provided an easy and effective guide to counting. If three samples of equal importance and complexity were to be examined using the same equipment, the length of counting for each would be cut in third so that three measurements could be made on each of the samples during one cycle. If the samples differed in complexity, some judgment had to be made on how to apportion the counting time; for the one-hour cycle, the first sample might have been counted for thirty minutes, the second and third for fifteen minutes each.

This schedule was typically followed for about $1\frac{1}{2}$ weeks. The first counts were of $2\frac{1}{2}$ minutes duration if the experimental objectives included observing nuclides with short half lives. The last counts on the schedule were for nearly two days each. Thereafter, measurements would be made whenever convenient and for up to a year following the end of the irradiation. These were for three to seven days each, and such counts greatly helped in determining more precise yields for long-lived nuclides. The extremely stable and reliable pulse-height analysis systems facilitated the long counting periods.

Table 4 illustrates the counting schedule utilized for one experiment, along with the measurements that were conducted after the

Table 4. Counting Schedule Experiment 63AU

Sample	Start Time	Length of Count	Shelf	% Dead Time
Calibration	7508211637	465 minutes	4	
63AU	7508220112	2.5	15	63%
63AU	0115	2.5		61%
63AU	0120	2.5		59%
63AU	0125½	5		57%
63AU	0137½	5		54%
63AU	0147½	5		52%
63AU	0157½	10		49%
63AU	0216	10		
63AU	0233	10		43%
63AU	0249½	20		39%
63AU	0319	20		34%
63AU	0350	20		31%
63AU	0418	40		29%
63AU	0516	40		24%
63AU	0608	40		21%
63AU	0656	80		18%
63AU	0830	80		16%
63AU	1004	80		13%
63AU	1134	80		
63AU	1304	160		
63AU	1600	160	15	9%
63AU	1855	320	5	27%
63AU	7508230150	320		
63AU	0820	320	5	18%
*Calibration	7508211310	110	3	
63AU	7508231448	640	6	23%
63AU	7508240315	640		
63AU	1600	640		
63AU	7508250415	1280		12%
63AU	7508260400	1280		10%
63AU	7508270245	1280	6	9%
63AU	7508280938	2560	3	14%
63AU	7508300900	2560		10%
63AU	7509010710	2560		9%
63AU	7509031606	7410	3	7%
Calibration	7509090036	483.3	3	5%

This concludes the continuous series of scheduled counting

Table 4. Cont'd.

Sample	Start Time	Length of Count	Shelf	% Dead Time
63AU	7510111638	4320	2	1%
Calibration	7510141746	930	2	
63AU	7601021547	5760	2	
Calibration	7601071143	240	2	3%
Calibration	7602171521	60	0	8%
63AU	1627	7200	2	
63AU	7603140239	2160	2	
Calibration	7603151506	15	0	

*The counting system had to be changed at this point because of a malfunction in the magnetic tape unit.

completion of the schedule.

2. Energy Calibration

An accurate knowledge of gamma-ray energies greatly aids the identification of the nuclides responsible. This requires a precise calibration to convert spectral channel information to the correct corresponding energies. To accomplish this in the experiments performed, spectra of isotopic standards were collected prior to and during any series of measurements. The computer program SAMPO⁴⁶ found the centroids of photopeaks in the standard spectra and also calculated peak shape parameters that were to be used in later SAMPO analysis of experimental spectra. A third-degree polynomial was least-squares fit through the points to provide a channel-energy conversion. The pulse-height analysis system was especially linear, and the corrections brought about by the second- and third-degree terms of the polynomial usually amounted to only a few tenths of a kiloelectron volt. The goodness of the curve fitting is attested to by comparing the data points with the calculated energy, as shown for the good case in table 5.

To perform the energy calibration, and also the efficiency assessment to be mentioned below, a National Bureau of Standards Mixed Radionuclide Gamma-Ray Emission-Rate Point-Source Standard (SRM 4216-B) proved especially useful. This nearly point source contained the isotopes listed in table 6. The initial activities contained in the source had been adjusted to provide a comparable number of counts in each photopeak, having taken into account typical relative detection

Table 5. Calculated Energy Calibration from Standard Spectrum

For spectrum channel X and energy E,

$$E = -0.19555 + 0.49922 X + 1.18944 \times 10^{-7} X^2 + 4.96307 \times 10^{-12} X^3$$

X	E(calculated)	E (gamma)
176.71	88.026	88.03
244.87	122.06	122.06
273.73	136.47	136.47
332.56	165.84	165.8
559.55	279.18	279.21
784.82	391.68	391.7
1029.7	513.99	513.98
1325.3	661.65	661.64
1798.4	898.02	898.0
2349.0	1173.2	1173.21
2667.6	1332.5	1332.48
3674.6	1836.1	1836.1

Table 6. Energy Calibration Standards

Nuclide	Energy (keV)	Half Life
Mixed Radionuclide Standard		
Cd-109	88.03	453 days
Co-57	122.06	270 days
	136.47	
Ce-139	165.8	137 days
Hg-203	279.21	36.7 days
Sn-113	391.7	115 days
Sr-85	513.98	65.2 days
Cs-137	661.64	30.1 years
Y-88	898.0	106 days
	1836.1	
Co-60	1173.21	5.26 years
	1332.48	
Bi-207 Standard		
Bi-207	569.6	30.2 years
	1063.4	
	1769.7	

efficiencies for each. With the passage of time, some standard isotopes, most notably ^{203}Hg and ^{85}Sr , decayed appreciably and were of less benefit in the calibrations. In some cases a separate ^{203}Hg source was included during counting of the mixed standard in order to augment the intensity of the 279-keV gamma ray. Another potential weak point in the energy calibration was the calibration curve's tremendous dependence in the high energy region on the data point coming from the ^{88}Y 1836-keV gamma ray. A ^{207}Bi source was on occasion also used in order to collect a data point for the energy 1770 keV, along with points originating from its two other gamma rays. Table 6 lists the gamma-ray energies used for calibration with the listed isotopes.

3. Measurement System

Samples were prepared for measurement by being mounted with cellophane tape on an aluminum counting card, 8.8 cm $\times$ 6.3 cm in size, that just fits in the precisely machined shelves of the holder attached to the Ge(Li) detector. It was experimentally determined that the maximum variation in counting geometry due to the changes in placement within any one shelf was 4%, and an attempt was made to reproduce the card's position in the shelf as closely as possible in order to reduce the magnitude of this error source.

In almost all cases, the distance between the sample and the detector was at least 2.2 cm. This reduced the difference between the efficiency for counting the sample and the efficiency as determined using a nearly point source. It also reduced the chances for sum peaking in the spectra.

Gamma-ray detection was performed using one of three 60-cm³ volume ORTEC coaxial-germanium diode with drifted-lithium compensation detectors. Ordinarily, all measurements for one sample were carried out using only one of the detectors. In the few cases where more than one detector was utilized, no systematic errors were observed. Table 7 contains data concerning detector resolution.

The efficiency for each of the detectors was measured using a set of calibrated sources obtained from the International Atomic Energy Agency or else a U.S. National Bureau of Standards standard containing a calibrated mixture of nuclides. The efficiencies determined as a function of energy for each shelf location and detector were least-squares fit with the following mathematical curve,

$$\text{Efficiency} = P_1 \times (E^{P_2} + P_3 \times e^{P_4 \times E})$$

as was done in reference 46.

The signal from a detector and its accompanying pre-amplifier was routed through a linear amplifier and, sometimes, followed by a pulse pile-up rejector. The last two elements were manufactured at Lawrence Berkeley Laboratory. The pulse-height analysis system also was assembled at LBL. It is based on a Texas Instruments 960A minicomputer, Northern Scientific NS-621 or NS-623 analog-to-digital convertor, 4096 memory locations for storage and Ampex magnetic tape deck. The system has provisions for recording a tagword, integrating counts between markers, finding the peak centroid, indicating on the magnetic tape the start time, stop time and live time for a measurement,

Table 7. Detector Resolution (FWHM)

Detector	122.1 keV (Co-57)	661.6 keV (Cs-137)	1332.5 keV (Co-60)
Ge(Li)#1	2.21 keV	2.49 keV	2.92 keV
Ge(Li)#2	1.28	1.60	2.00
Ge(Li)#3	1.37	1.69	2.05

Ge X-ray detector FWHM = 0.59 keV for the 59.5 keV gamma ray of Am-241

and other options. Active base-line restoration was found to be useful for the high count rates encountered while collecting gamma-ray spectra. It was found useful to set the lower-level discriminator so that nearly all X-ray peaks would be excluded from the spectra; this helped reduce dead time.

On many occasions the dead time meter indicated greater than 50% for the initial measurements made on a target foil, but the photopeaks found in such a spectrum showed only small degradation in width and no significant energy shift. Information obtained from such spectra did not indicate any systematic biasing of the results.

On a few occasions use was made of a Hewlett-Packard 5401 pulse-height analysis system, but the results obtained and methods used were similar to those described above.

Extensive background spectra were assessed to learn which gamma rays would be found in a spectrum regardless of the type of sample facing the detector. This determination was especially important for evaluation of any spectrum collected over a long time period. Fortunately, no artificially produced isotopes were ever detected in the background. Found were ^{40}K and members of the thorium and uranium decay chains.

The detector and sample were contained in a shielded "cave" to lessen the contribution of the natural and artificial background to the spectra. The shielding consisted of 5 cm of lead and a further 0.3 cm steel and 0.3 cm aluminum to reduce the interference from fluorescence induced in the lead.

D. Human-aided Computer Analysis of Gamma-ray
Spectrometric Experiments

A tremendous amount of digital data is amassed from the measurements made on the sample(s) in one experiment. Making sense out of all this information within a reasonable length of time requires dependence upon the "number crunching" ability of digital computers. An extensive series of computer programs has been developed to handle the data and extract from them the desired information. Figure 13 portrays the information processing pathway. This method of analysis has been developed over the past several years, and many members of the SHEIKS group at Lawrence Berkeley Laboratory have contributed to it.* The analysis of data from one experiment can be completed by one person in a month or less if adequate energy is put into the effort and expense is no hindrance; two months would be a more typical period for an analysis.

Despite the great calculating capability of the digital computer, knowledgeable human intervention can greatly increase the power of this system of analysis. It is only with difficulty and expense that a computer algorithm can duplicate the ability to judge, choose among plausible alternatives, decide on risk-taking, avoid mathematical pitfalls, and dig a little deeper into the data to extract more useful information. Graphical displays are used at several stages of the analysis to facilitate recognition of patterns and inconsistencies.

* M. DiCasa, M. M. Fowler, J. V. Kratz, R. Klein, R. Kraus, D. Lee, J. O. Liljenzin, A. E. Norris, R. J. Otto, and the author.

The two complementary techniques contribute their individual strengths to the data analysis process and yield an effective and expeditious method for obtaining the desired end products from much or little, good or poor input.

1. Peak Search and Fit

After collecting numerous gamma-ray spectra originating from an experiment, one is faced with the task of locating the many gamma-ray full-energy peaks (commonly called photopeaks) and accurately measuring their areas. The computer program SAMPO⁴⁶ is designed for this purpose and was so used.

The gamma-ray spectra to be examined were recorded on magnetic tape, thus facilitating computer analysis. The spectral energy range examined was 90 keV to 2000 keV. It was found that the region below 90 keV was too cluttered with X-ray peaks and with overlapping gamma rays to be of much use. In addition, many nuclear transitions with energies below this threshold are highly converted and, therefore, yield their corresponding gamma rays in low abundance. Nuclides with gamma rays greater than 2000 keV in energy normally have very short half-lives, very low abundances for these gamma rays and higher intensity gamma rays of lesser energy. In addition, detector efficiency for high energy photopeaks is rapidly decreasing with increasing energy, and single-escape and double-escape peaks become prevalent. For all of the above reasons, the upper level of the pulse-height analysis system was set to about 2000 keV.

The program SAMPO requires various input parameters to process a spectrum. The methods for obtaining the energy calibration curve and the detector efficiency curve as a function of sample location have already been described. SAMPO fits each photopeak with a Gaussian curve coupled to exponential tails at the two extremities; it requires the input of descriptions of peak shapes in order to define as a function of energy the width of the Gaussian and the locations for coupling the exponential tails to the Gaussian. These parameters were determined from the reference peaks taken in the energy calibrations for the same experiment, and SAMPO performs a linear interpolation for intermediate energy values. Also input are a spectrum title card and the length of the counting period.

The gamma-ray spectra were very complex, and due to the superb resolution of the Ge(Li) detectors, an early spectrum could contain more than two hundred resolvable photopeaks within the region of interest. SAMPO contains the capability to automatically locate photopeaks, but this proved inadequate for searching through such complex spectra. Rather, use was made of a Control Data Corporation VISTA graphical display console. SAMPO was operated interactively allowing human judgement to supplement the program's peak finding results and to oversee the fitting performed. The interactive mode was applied to the complex spectra until it was seen that SAMPO's own search and fitting routines could adequately handle the information; SAMPO processed the remaining spectra using the automatic mode.

In the earlier stages of this project, spectral peaks were found and fitted using the computer program Automatic Evaluation of Spectra (AES) developed by J. O. Liljenzin. This program, only capable of operating in the automatic mode without human intervention, was not capable of processing the complex spectra obtained when a target foil was directly counted without application of chemistry to simplify the mixture of nuclides. AES used the double-difference method for finding peaks and calibrated gaussian curves to fit them. The peak areas so determined were commonly 10% off the better fitting SAMPO-determined value. This seemed mostly due to not considering Gaussian tailing of the photopeak.⁴⁷

The results obtained from the SAMPO program were recorded on punched cards, one card for each photopeak. This card contained the peak centroid in channel number and in keV, peak area in counts and corrected for detector efficiency, corresponding counts per minute, the associated error for each of these terms, and an identification label. A photographic picture on microfiche was made of each fitted region so that one could later review the quality of the peak search and fitting. Figure 14 pictures regions of a gamma-ray spectrum that have been fit by computer program SAMPO.

2. Decay-curve Construction

The second step in the computer analysis required searching the various spectra from one sample to find which ones contain the photopeak of one particular energy and tabulating the associated photopeak magnitude that had been corrected for efficiency within

SAMPO. The computer program designed to do this job is named TAUI.

The punched card input data for TAUI consists of the following components:

- 1) One card listing the date and time of the end of the accelerator bombardment that produced the sample(s) in question;
- 2) At the head of each spectrum's data, a card containing the date and time that the counting period started, the length of the count and a four-character identification name for that particular sample which would be used for all spectra of that one sample;
- 3) The SAMPO cards mentioned above that describe the photopeaks of that one spectrum in ascending energy order; and
- 4) A blank card that delineates the end of data for one spectrum.

One should note that spectra from several samples can be mixed in one computer run as long as they originated from one experiment and each sample is given a different four-character code word. The spectra from one sample must be in chronological order starting with the earliest, but spectra from other samples may be interspersed.

The program associates the mid-point time and date of the measurement with the spectrum. Since this is based on the start time and the live time of the count, no correction is made by the program for counting dead time. Usually this did not create a serious error, but the supposed start time was adjusted in cases of relatively high dead times to minimize this error. Choosing the mid point of the

counting time results in a 2% error or less in the decay curve if the nuclide's half life is less than the length of count, and the counting schedule was designed, as noted earlier, to insure this.

The program finds the photopeak with the lowest energy and associates with it photopeaks appearing in other spectra that fall within an energy window of interest. The center of this window is located at the mean energy value of the photopeaks already accepted, and the window width has been empirically set at the value,

$$\text{window} = 2 \times \text{ETEST} = 2 \times (\log_{10} \text{EMEAN} - 1.5),$$

yielding an acceptance window of 1 keV at an energy of 100 keV and 3 keV at 1000 keV. Photopeak data accepted for a decay curve are removed from the remaining information and are, thus, avoided in subsequent search cycles. Decay curves consisting of two or fewer points are discarded unless the two points occur in the first two spectra.

A decay curve is prepared for each set of photopeak data, and a least-squares fit performed to obtain an estimate of the half life of the nuclide responsible for the gamma ray. A check is made to determine if a better fit would result from using the sum of two activities. The printed results list for each sample the energies corresponding to the decay curves along with the estimated half lives, errors in half life, the extrapolated count rates at the end-of-bombardment time, the accompanying errors in count rate, the number of spectra containing photopeaks of the appropriate energy, which spectra these are and how many data points were eliminated from the

decay curve because of large deviations.

In addition, a magnetic tape is produced containing necessary data to describe each of the decay curves. This tape will be a portion of the input for the next stage of the analysis.

3. Nuclidic Identification

Information has been obtained to facilitate identification of the nuclides responsible for the gamma rays observed. Available are the decay curves and corresponding half life and possibly growth data, energies of the gamma rays, and chemical properties of the elements if chemical processing of the sample has been performed. All this is brought together for the computer program TAU2.

Computer program TAU2 also makes use of the Control Data Corporation VISTA graphical display system. The tape prepared by TAU1 contains all the knowledge necessary for constructing the decay curves and serves as part of the input for TAU2. Another necessary ingredient is an extensive table of gamma-ray data; this will be further described below. The last vital component is the judicious human intervention during the interactive computer operation of TAU2.

The program displays one decay curve at a time in typical semi-logarithmic form on the cathode-ray-tube screen. Also seen are the calculated energy of the gamma ray and the four-character code word of the sample. Near the top are listed twenty entries from the gamma-ray table which come closest in energy to the calculated value associated with the decay curve. The human operator considers the printed listing from program TAU1 that gives an estimate for the half life,

the half lives of the candidates on the screen, the gamma-ray abundances of the good choices, the energy agreement, the likelihood of production for the nuclides, and the possible prior observation in this or similar samples of the nuclides listed or nuclides neighboring in atomic number or mass number. He then chooses one of the candidates via the keyboard of the VISTA, and the program performs a least-squares fit to the decay-curve data points using the half life of the chosen nuclide.

If the choice is acceptable, the operator signifies so using the keyboard, and a Hollerith card is punched. If the fit is unsatisfactory, further choices can be made until the operator is satisfied. Even if the first choice is acceptable, there may be further candidates that appear to be equally good, and further fits also accepted, leaving the final decisions for later stages of the analysis. If the operator is not convinced by the decay-curve fits offered, he can rotate the list of choices to higher or lower energy and expand the number of possibilities.

He has the option of fitting a straight line through two points he selects on the semi-logarithmic plot. If this route is taken and accepted, the punched result card lists the half life calculated from the slope of the line chosen, the TAU1 energy estimate, the activity extrapolated to time zero uncorrected for the unknown gamma-ray abundance, and the accompanying error.

The decay curve may portray the sum of two activities. In that case, the operator can select two entries from his list, put two lines

through the points of his choosing, or take one from the list and the second from his fit.

If the decay curve indicates growth and decay of the activity, this also can be handled by TAU2. The gamma-ray table includes much information on nuclidic parents, parent half lives and feeding percentages. The results, if accepted, are punched on two cards, one for the parent, corrected for feeding percentage, and one for the original activity of the daughter at time zero.

A constant background can be added to the activity chosen from the list.

Occasionally, some data points contributing to the decay curve sharply conflict with the general trend indicated by the vast majority of the data points. The operator has the option of eliminating such discordant points from the fitting calculation.

If any of the options has been selected, the operator can restore the decay curve to the original, linear-fit picture by choosing the "reset" option.

When a calculated fit is accepted, a punched card is prepared. This card lists the nuclide chosen, its half life, gamma-ray energy, the energy calculated in TAU1, gamma-ray abundance, an asterisk to denote cases of relative abundance, the calculated activity of the nuclide at the end-of-bombardment time, the associated error, the sample identification and the type of fit that had to be made. The types can be linear, sum, growth, or background-added. The card also indicates if the activity is that of a parent, if the growth option

was taken, or the daughter at time zero. The punched cards contain the information necessary to calculate the cross section for the nuclide, as will be done in the next step of the analysis. Also, the cathode-ray-tube display of the fit to the curve is recorded on microfiche so that one can return to it if questions should arise.

Figures 15-19 show examples of linear fit, sum fit, growth and decay, and a fit through points chosen by the operator.

4. Gamma-ray Table

A gamma-ray energy and intensity table⁴⁸ has been prepared for use in the identification and yield determination of nuclides contained in samples obtained in radiochemical and nuclear chemical experiments. The primary use for this table has been the role it plays in the computer-aided analysis of gamma-ray spectra.

Because of the practical limitations inherent in the experiments for which the list was originally intended, the following three criteria were applied for the acceptance of an entry:

- 1) The half life of the nuclide must be at least five minutes, or else it must be the daughter of such a qualifying parent;
- 2) the abundance of the gamma ray must be at least one half of one per cent; and,
- 3) the energy of the gamma ray must be greater than 90 keV.

X-rays were normally not included because a sample will usually contain a mixture of isotopes for any one element. The above conditions greatly trimmed the list which leads to easing the identification process, increasing the chances of a proper identification, decreasing

the amount of computer storage necessary to contain the data and lessening of computer expenses. These are accomplished with very little loss in capability. In some cases, gamma rays with intensities greater than one-half per cent were not included when numerous additional gamma rays with greater abundance existed for the same nuclide and the half life was such that it would be unlikely that an overwhelming amount of that nuclide would be observed in a sample. In cases where a parent nuclide has a half life significantly longer than that of the daughter, the gamma rays of the daughter are often included as also originating from the parent.

The energy table includes for each entry the element symbol, mass number, atomic number, half life and information about which chemical sample should contain the element when a particular chemical separation scheme is used.⁴¹ If only the relative gamma-ray abundance is known, this is so indicated by an asterisk following the abundance value. An unknown abundance is given the value -0. Additional information is contained concerning the nuclide's parents (a maximum of three), the parental half lives, and the branching ratios. Again, such data is included if the parental half life is adequately long and the feeding from the parent is significantly large.

The sources for this material were primarily compilations of similar data.⁴⁹⁻⁵⁷ Constant updating from the current literature has contributed to the list. More meaningful experimental results require knowledge of the absolute abundances of gamma rays. Appropriate calculations and/or judgments based on published data often enabled

making such determinations or estimations.

The information has been encoded for computer use and storage. Computer programs have been written to permit editing the energy-sorted list and to produce from the energy source list a table with gamma rays sorted by nuclide.

The energy table contains 9299 energy entries.

5. Review of Results and Calculation of Yields

The punched output from program TAU2 is listed to point out where multiple identifications have been made for one decay curve and to create a master copy of all the identifications originally obtained for each sample. The cards for each sample are then sorted according to mass number and atomic number to group together the results of each nuclide, and such a printed listing is prepared.

The results are reviewed to weed out incorrect assignments and to improve the findings. Where several gamma rays provide information on the activity of one nuclide, a check is made to see whether the results are in harmony or if there is any disagreement. If the values conflict, an attempt is made to reconcile the differences or to learn which values are in error. If only one value is available for a particular isotope, one has to ascertain whether the result originates from that nuclide's most prominent gamma ray or if there are other gamma rays that should be equally or more abundant and were not observed. If two equally valid values are available for a particular nuclide and they don't agree, a cross-sectional value will have to be evaluated separately from each of the values and a judgement later made as to which is more in harmony with results found for neighboring nuclides.

In cases of multiple identifications for one decay curve, one attempts to match up any of the activities determined with more positive results obtained from different gamma rays from the same nuclides. A match in activities at time zero usually confirms the nuclidic identity. If the time-zero activity greatly exceeds that as determined from other gamma rays and its abundance is such that it is expected to be seen, the difference in activities can be attributed to the other possible choices. This last case most commonly occurs for two isomeric states of an isotope. If the multiple identifications cannot be resolved at this stage, it is possible to independently calculate the yield for each and compare results with those of neighboring nuclides.

After the punched-card results are corrected as well as possible, one is ready to proceed to the computer program CROSS. One supplies the program with the integrated beam current, the average charge of the beam projectiles, the target thickness, the length of the bombardment and the atomic weight of the target element. Following is a group of result cards for each nuclide of the sample separated from other groups by a blank card.

Program CROSS calculates for each nuclide an average cross-sectional yield based on the time-zero activities of its gamma rays and weighted according to the precision of each. If any individual activity differs from the calculated weighted mean by more than three standard deviations, the discordant value is discarded, and a new weighted mean is calculated. The program punches card output for each

nuclide listing the nuclide mass number, atomic number, element symbol, cross section, standard deviation from the cross-sectional calculation, and nuclidic half life. It is also possible to include the time between the end of the accelerator bombardment and the chemical separation that isolated the nuclide from its genetic parents. This information is necessary for the computer program used in the next stage.

In a few cases, the standard deviation exceeds the value of the accompanying cross section. If the excess is not too extreme, the standard deviation is reset to 99% of the cross section. This adjustment allows plotting cross-sectional yield and error of the individual nuclides in a semi-logarithmic form. The error estimates often surpass a more reasonable amount, especially in cases of a sum fit to a decay curve.

When the cross section is calculated from just one gamma ray, the standard deviation is sometimes inappropriately low. To counter this, when the standard deviation is less than 1% of the cross section, it is reset to 10%. This is more in line with the results determined in cases of more than one gamma ray contributing to the calculation for one nuclide.

In most cases the standard deviation ranged from 5% to 20% of the cross section.

An option is available to break up the accelerator bombardment time into segments, each with its own length of bombardment and integrated beam current. This option is used in cases of the accelerator beam current having varied significantly during the

bombardment or the occurrence of beam lapses for extensive periods of time. Yields coming from experiments involving chemical processing are now corrected for chemical yield. The chemical yield for a particular element contained in one sample is determined by comparing the yields of one or several well-measured isotopes observed also when a target is bombarded and no chemistry performed. The standard isotopes are chosen to provide independent or completely cumulative yields under the experimental conditions.

6. Estimate Independent Yields and Total Isobaric Yields

The cross-sectional yields calculated in program CROSS are usually partially cumulative because any radioactive parent produced by the nuclear reaction can decay to the daughter during the bombardment, the time between the end of bombardment and the isolation of the daughter element from its parent by chemistry, and the time that the sample is being counted if parent and daughter have not been separated. Now, a model is applied to estimate the independent yield of a nuclide and the contribution of ancestors to the activity of that nuclide.

The basic assumption to be made here is that the distribution of independent yields of isobars coming from one reaction mechanism is distributed normally about a central value. Such an assumption is not unwarranted in light of the evidence^{20,34} for a random-walk process occurring in the exchange of nucleons between the target and projectile during the deep-inelastic collisions and results found here (figure 20) and elsewhere.⁵⁸⁻⁶⁰

The punched-card output obtained from program CROSS must have added to it information on the parent atomic number and half life. The equations used to determine the contributions of the daughter independent yield, parent decay during the bombardment, and parent decay after the bombardment to the calculated original activity of the daughter are from reference 61. In addition, each contribution is weighted by the magnitude of its nuclide's ordinate on the Gaussian curve. Also, all parent factors have an added weighting of $(y_{\text{par}} + y_{\text{gp}})/y_{\text{par}}$ as determined by the Gaussian ordinates to account for the contribution of the grandparent. Two simplifications are made here, but they tend to balance each other out. Firstly, the half life of the grandparent is here arbitrarily set to zero, and it is almost always true that the grandparent's half life is shorter than that of the parent and certainly far shorter than the daughter's. Still, the effect of this simplification is to overestimate the contribution of the grandparent. This is somewhat balanced out by ignoring the contributions of earlier ancestors. In any case, the ordinates of these early ancestors (including that of the grandparent) is typically very low on the Gaussian curve, and so is their corresponding contributions to the observed yield.

In cases of the parent having a longer half life than that of the daughter, it is assumed that the daughter's yield is independent of the parent's; if the parent's contribution had been very significant, the apparent half life from the decay curve would be that belonging to the parent or an intermediate half-life value. If the daughter's

time-zero activity has been calculated in program TAU2 using the growth-and-decay relations, the resulting yield is treated as being independent.

The calculated independent yield of a nuclide is made equal to the experimental yield multiplied by the fraction of the daughter contribution out of the sum of contributions outlined above. The total chain yield is arrived at by summing the Gaussian ordinates for all isobars significantly contributing to the chain yield, dividing the sum by the Gaussian ordinate of the daughter, and multiplying the calculated independent yield by this factor.

To use this formalism, one must know the parameters that describe the Gaussian curve. The curve is determined by its height, width and center. There is a curve for each mass number. One starts with some formulation to choose the center of the Gaussian curve and another for the width. Equal-charge-displacement or unchanged-charge-distribution algorithms can be selected, or one can elect to use an empirical description for the curve center. For these experiments the empirical route was chosen. An initial estimate of the width was prepared by plotting the independent yields of shielded nuclides and plotting nuclidic yields obtained from chemistry experiments. These initial guesses are used for one calculation in order to obtain better estimates. Results are recycled in this iterative process until they are deemed satisfactory. The few data points that greatly deviate from the Gaussian distribution are highly suspect and deserve thorough checking. Almost always, such points are not based on data from several gamma rays yielding consistent time-zero activities.

If one had three perfect isobaric data points, it would be possible to exactly calculate the Gaussian curve for that mass number.

Unfortunately, nature is not cooperative, and certain compromises have to be made. However, it is expected that gradual changes in yields occur as one traverses mass number, atomic number and neutron number. The data collected in these experiments is insufficiently precise to define fine structure in the distribution of yields, so in using a smooth model for the distribution one is not forsaking learning about the finer points of the yields.

To cope with inadequate information to define the Gaussian distribution for one mass number, one uses all the data available in a sufficiently small neighborhood and checks to make sure that indeed the data points all contribute to forming one Gaussian. The calculated independent yields in the neighborhood are plotted as a function of displacement from the Gaussian center for the corresponding mass numbers. The difference between the assumed center of the model Gaussian distribution and the apparent center of the yields can be used to reassess the function defining the center. The width of the distribution plotted can also help better characterize the width parameter of the Gaussian. The refinements can be put back into the calculation for another iterative step to improve the results.

More than one Gaussian formulation may be necessary to completely describe one nuclear reaction system. In a few neighborhoods, two formulations may overlap; this can occur when two reaction mechanisms (e.g., quasi-elastic and deep-inelastic mechanisms) are both producing

nuclides in one neighborhood. The sum of yields from the two mechanisms is observed in an experiment.

Computer program AZYIELD carries out the computations described above.

Figure 20 depicts the Gaussian curve and calculated independent yields obtained from one experiment and covering one mass region.

7. Plot of Mass Yield and Factorization into Mechanistic Components

Once satisfactory calculations for the total chain yield as a function of mass number are obtained, these are graphed, and an attempt is made to factor the yields into contributions from the known reaction mechanisms. The distribution of yields for each mechanism is set to be Gaussian-shaped as a function of mass number, with one very important exception to be discussed later. Some good estimates for the Gaussian-curve parameters can be initially made from the data plot, especially if the more significant yields originating from one reaction mechanism do not overlap with yields coming from another mechanism.

Computer program PLOT prepares a graph containing the calculated Gaussian curves for the individual reaction mechanisms and the sum of all the yield curves as a function of mass number (figure 38). Also, the sum curve is plotted along with the total chain yields calculated from the data (figure 37). Finally, the program adds up the calculated yields for each reaction mechanism to give a total cross-sectional yield for that mechanism.

The results from one complete calculation are examined to refine the Gaussian parameters in order to develop a better fit to the data. In some cases, insufficient data is available to adequately guide the Gaussian fit. A good example of this is to be found in the region of the projectile in the 252-MeV $^{20}\text{Ne} + ^{197}\text{Au}$ experiments (see figure 27 and table 8). Very few nuclides exist around the target with half lives and gamma-ray properties that allow their measurement by the methods used here. (On-line particle detection techniques are much better suited to making such measurements.⁶²) The way taken out of this adverse situation is to use Gaussian parameters based on those found for the complementary target region.

The calculated Gaussian fit for the deep-inelastic mechanism is found to be deficient in the yields around symmetry from the reactions $^{84,86}\text{Kr} + ^{197}\text{Au}$. A better fit is made by smoothly changing from the Gaussian curve to an exponential decay as one approaches symmetry. The continuity is enforced by requiring both equations to have the same value and first derivative at the transition point. The transition point was found empirically to be one half of the full-width-half-maximum parameter above or below the corresponding center of the Gaussian curves for the two branches of the deep-inelastic mechanism.

Fits to mass-yield curves are in figures 27-38, and integrated yields are tabulated according to projectile and mechanism in table 14.

III. RESULTS

A. Nuclidic and Isobaric Yields

The cross-sectional data obtained from the preceding experimental work are listed in tables 8-13. The yields are equivalent to integrating the true cross section from the maximum energy down to the Coulomb barrier:

$$\sigma = \int_B^{E_{\max}} \frac{d\sigma}{dE} dE / (E_{\max} - B)$$

Besides identifying the nuclide by element symbol, mass number, atomic number and, perhaps, isomeric state, the list catalogues the yield measured experimentally for each acceptable nuclide, the calculated fraction of this yield that is attributed to the independent production of the nuclide based on the assumptions discussed earlier, and the calculated total mass yields for the corresponding mass number based on the same model. The errors associated with the measured yields are almost completely attributed to counting errors and, when more than one gamma ray was observed, a weighted averaging of the several results for that nuclide.

The results are segregated according to projectile and experiment.

Following the tables of results are plots of the individual nuclidic cross-sectional yields as functions of projectile and mass number (figures 21-26) and the calculated mass-yield results and fits to the results (figures 27-38). The uncertainty for the calculated

252-MEV NE-20 + AU-197

NUCLIDE A Z	EXPERIMENTAL YIELD(MB)	FRACTION INDEPENDENT	CALCULATED MASS YIELD(MB)
EXPERIMENT 53AU 252-MEV NE-20 + AU-197			
NA 22 11	.577+/-	.457	.2265
NA 24 11	1.957+/-	.763	.9193
MG 28 12	.198+/-	.069	.9530
K 43 19	.846+/-	.085	.8626
SC 46 21	.145+/-	.040	1.0000
CA 47 20	.158+/-	.015	.9186
SC 48 21	.320+/-	.031	1.0000
MN 54 25	.335+/-	.093	1.0000
CO 58 27	.220+/-	.007	.9728
FE 59 26	1.688+/-	.032	.7378
CO 60 27	1.245+/-	.036	1.0000
ZN 65 30	.407+/-	.020	.8856
CU 67 29	4.564+/-	.456	.7639
ZN 72 30	.774+/-	.712	.8992
GA 72 31	5.994+/-	3.389	1.0000
AS 72 33	9.268+/-	3.017	1.0000
AS 74 33	3.271+/-	.327	1.0000
SE 75 34	2.243+/-	.401	.8304
AS 76 33	9.071+/-	.614	1.0000
BR 77 35	1.117+/-	.121	.8576
BR 82 35	10.230+/-	.146	1.0000
RB 83 37	6.205+/-	.294	.9245
RB 84 37	8.805+/-	.153	1.0000
SR 85 38	5.705+/-	.571	.8609
RB 86 37	14.330+/-	.533	1.0000
Y 86 39	1.493+/-	.214	1.0000
Y 87 39	5.284+/-	.162	1.0000
Y 87M 39	5.361+/-	.344	.8673
Y 88 39	9.876+/-	.129	.6607
ZR 89 40	3.857+/-	.386	.8950
SR 91 38	7.756+/-	.476	.8300
NB 91M 41	1.691+/-	.597	1.0000
NB 92M 41	.423+/-	.027	1.0000
MO 93M 42	1.842+/-	.184	1.0000
ZR 95 40	10.700+/-	1.151	.7541
NB 95M 41	.242+/-	.009	1.0000
TC 95 43	1.750+/-	.432	.9422
NB 96 41	19.460+/-	.492	1.0000
TC 96 43	3.086+/-	.244	1.0000
ZR 97 40	2.763+/-	.276	.8755
RU 97 44	1.190+/-	.121	.9525
MO 99 42	19.480+/-	.969	.6541
RH100 45	2.094+/-	.324	1.0000
RH101 45	.999+/-	.275	.9397
RH101M 45	1.974+/-	.370	1.0000
RH102 45	3.248+/-	1.764	1.0000
RH102M 45	6.109+/-	.817	1.0000
RU103 44	35.120+/-	2.604	.5283
RH105 45	34.549+/-	3.455	.4936
AG105 47	2.119+/-	.344	.9472
RU106 44	5.279+/-	.059	.8084
AG106M 47	3.290+/-	.126	1.0000
AG110M 47	12.830+/-	.350	1.0000
			.52
			31.00+/-
			11.50+/-
			4.81+/-
			.43+/-
			2.46+/-
			1.98+/-
			.88+/-
			.71+/-
			3.84+/-
			3.12+/-
			1.50+/-
			11.78+/-
			7.75+/-
			19.57+/-
			52.25+/-
			9.25+/-
			8.55+/-
			23.72+/-
			5.73+/-
			31.39+/-
			23.09+/-
			26.15+/-
			25.04+/-
			36.64+/-
			18.93+/-
			35.77+/-
			31.48+/-
			27.48+/-
			32.56+/-
			31.40+/-
			23.30+/-
			3.06+/-
			38.88+/-
			26.16+/-
			.63+/-
			55.92+/-
			49.07+/-
			46.28+/-
			18.66+/-
			64.78+/-
			33.23+/-
			78.87+/-
			15.36+/-
			32.30+/-
			26.91+/-
			50.60+/-
			47.06+/-
			45.83+/-
			84.13+/-
			17.95+/-
			58.86+/-
			35.11+/-

XBL 776-9027

IN110M	49	2.456+/-	.569	1.0000	114.80+/-	26.59
AG111	47	24.081+/-	2.408	.6162	37.21+/-	3.72
IN111	49	5.661+/-	.239	.9253	102.67+/-	4.34
PD112	46	29.380+/-	2.938	.8590	160.12+/-	16.01
SN113	50	3.858+/-	.365	.9386	113.14+/-	10.71
IN114M	49	11.010+/-	.888	1.0000	39.79+/-	3.21
SB118M	51	12.010+/-	1.505	1.0000	69.34+/-	8.69
TE118	52	2.412+/-	.144	.9414	78.66+/-	4.68
TE119M	52	4.499+/-	.092	1.0000	68.68+/-	1.41
SB120B	51	8.928+/-	.204	1.0000	25.49+/-	.58
TE121M	52	7.996+/-	.396	1.0000	37.49+/-	1.86
SB122	51	5.267+/-	.303	1.0000	13.70+/-	.79
7E123M	52	7.262+/-	1.327	1.0000	19.27+/-	3.52
I 123	53	18.330+/-	2.974	.8588	96.49+/-	15.66
I 124	53	8.795+/-	.312	1.0000	34.50+/-	1.22
XE125	54	9.961+/-	.498	.8830	73.91+/-	3.70
I 126	53	5.478+/-	1.358	1.0000	13.92+/-	3.45
XE127	54	12.680+/-	.262	.8058	34.55+/-	.71
BA128	56	1.101+/-	.195	.9461	44.64+/-	7.89
CS129	55	14.050+/-	2.182	.8127	46.81+/-	7.27
BA131	56	13.530+/-	.407	.8429	59.45+/-	1.79
CS132	55	1.136+/-	.273	1.0000	2.89+/-	.70
LA132	57	6.618+/-	2.258	.9084	78.83+/-	26.90
BA133	56	8.152+/-	1.600	.7208	16.14+/-	3.17
BA133M	56	2.429+/-	.276	1.0000	6.67+/-	.76
CS134	55	.222+/-	.031	1.0000	.88+/-	.12
BA135M	56	5.944+/-	.594	1.0000	15.86+/-	1.59
CE135	58	4.793+/-	.744	.8919	41.56+/-	6.45
CE139	58	4.850+/-	.485	.6384	7.79+/-	.78
CE141	58	1.110+/-	.284	.7759	2.76+/-	.70
PR142	59	1.841+/-	1.307	1.0000	4.63+/-	3.29
PM143	61	2.536+/-	.538	.8784	17.71+/-	3.76
PM144	61	1.302+/-	.103	1.0000	6.17+/-	.49
EU145	63	.468+/-	.094	.9622	47.90+/-	9.61
PM146	61	.342+/-	.065	1.0000	.91+/-	.17
EU146	63	.720+/-	.162	1.0000	28.32+/-	6.36
EU147	63	1.569+/-	.340	.9748	25.95+/-	5.63
EU148	63	.763+/-	.090	1.0000	6.51+/-	.76
EU149	63	1.733+/-	1.000	.9884	8.55+/-	4.93
GD151	64	.512+/-	.071	.9274	3.14+/-	.43
TB155	65	.737+/-	.074	.8369	2.18+/-	.22
TM160	69	.585+/-	.027	1.0000	1.51+/-	.07
VB169	70	.177+/-	.055	.8700	.41+/-	.13
HF173	72	.958+/-	.164	.7824	2.57+/-	.44
HF178M	72	1.037+/-	.733	1.0000	5.11+/-	3.61
HF179M	72	.098+/-	.097	1.0000	.82+/-	.82
RE181	75	.537+/-	.531	.7477	1.25+/-	1.24
RE182	75	.734+/-	.073	.8001	1.53+/-	.15
RE182M	75	1.062+/-	.337	1.0000	2.76+/-	.88
RE184M	75	2.648+/-	.345	1.0000	7.55+/-	.98
IR187	77	14.930+/-	2.148	.6668	26.26+/-	3.78
IR188	77	.377+/-	.171	1.0000	.95+/-	.43
PT188	78	1.121+/-	.041	.7940	3.43+/-	.12
PT191	78	5.431+/-	1.091	.5274	7.40+/-	1.49
IR192	77	.043+/-	.016	1.0000	.41+/-	.15
MG193M	80	6.450+/-	1.026	.8017	20.83+/-	3.31
IR194M	77	.070+/-	.012	1.0000	.40+/-	.07
AU194	79	10.650+/-	.691	1.0000	67.71+/-	4.39
AU195	79	35.389+/-	.750	.9880	90.75+/-	1.92
MG195M	80	9.588+/-	.959	1.0000	24.48+/-	2.45
AU196	79	59.940+/-	21.950	1.0000	308.08+/-	112.82
AU196	79	59.940+/-	21.950	1.0000	97.46+/-	35.69

HE197M	80	20.680+/-	1.837	1.0000	84.14+/-	7.47
AU198	79	7.588+/-	.646	1.0003	135.11+/-	11.49
TL198	81	67.211+/-	4.837	.5809	97.88+/-	7.04
AU199	79	15.557+/-	.160	.9462	613.47+/-	6.31
AU199	79	15.557+/-	.160	.9820	77.55+/-	.80
TL199	81	52.551+/-	4.803	.4638	65.44+/-	5.98
AU200M	79	1.169+/-	.117	1.0000	20.20+/-	2.02
TL200	81	22.050+/-	1.599	.5075	37.50+/-	2.72
PB200	82	16.130+/-	1.750	.6426	26.73+/-	2.90
TL201	81	7.538+/-	.927	.3021	11.10+/-	1.36
PB203	82	2.702+/-	.123	.3881	4.07+/-	.18
BI204	83	2.044+/-	.169	.4870	2.63+/-	.22
BI205	83	1.975+/-	.113	.3710	2.37+/-	.14
BI206	83	.626+/-	.138	1.0000	2.90+/-	.64
P0206	84	2.267+/-	.227	.5511	3.15+/-	.31

EXPERIMENT 54AU

252-MEV NE-20 + AU-197

NA	24	11	1.726+/-	.173	.9193	27.34+/-	2.73
MG	28	12	.323+/-	.145	.9530	18.81+/-	8.46
CA	47	20	.182+/-	.009	.9186	2.83+/-	.15
SC	48	21	.277+/-	.036	1.0000	1.72+/-	.22
MN	52	25	.367+/-	.045	.9968	1.66+/-	.20
MN	56	25	1.606+/-	.095	.7815	3.52+/-	.21
FE	59	26	1.638+/-	.050	.7379	3.73+/-	.11
CU	67	29	4.629+/-	.463	.7640	11.95+/-	1.19
ZN-71M	30		1.448+/-	.408	1.0000	8.86+/-	2.50
GA	72	31	6.621+/-	.505	1.0000	21.61+/-	1.65
GA	73	31	3.121+/-	.551	.8246	12.05+/-	2.13
GA	74	31	.901+/-	.892	.8766	6.18+/-	6.12
AS	74	33	3.160+/-	.654	1.0000	8.94+/-	1.85
AS	74	33	4.023+/-	.391	1.0000	10.52+/-	1.02
AS	78	33	0.027+/-	.371	.9814	35.08+/-	1.62
SE	81M	34	4.259+/-	.426	1.0000	23.17+/-	2.32
BR	82	35	9.003+/-	.331	1.0000	27.62+/-	1.02
RB	82M	37	2.540+/-	.765	1.0000	16.15+/-	4.87
SE	83	34	2.566+/-	1.222	.9240	46.33+/-	22.07
BR	84	35	2.926+/-	.506	.8872	17.77+/-	3.07
BR	84M	35	1.954+/-	.714	1.0000	13.38+/-	4.89
RB	84	37	9.628+/-	.955	1.0000	29.19+/-	2.84
RB	84M	37	5.592+/-	.124	1.0000	16.61+/-	.37
V	84	39	.536+/-	.321	.9828	37.03+/-	22.16
KR	85M	36	4.777+/-	.478	.8065	13.39+/-	1.34
V	86	39	1.041+/-	.139	1.0000	13.20+/-	1.77
V	86M	39	.742+/-	.091	1.0000	9.41+/-	1.15
KR	87	36	1.082+/-	.236	.8917	8.56+/-	1.87
V	87	39	4.484+/-	.605	1.0000	30.35+/-	4.10
V	87M	39	5.046+/-	.505	.9883	33.76+/-	3.38
KR	88	36	4.720+/-	4.673	.9207	77.53+/-	76.76
RB	88	37	6.019+/-	.686	1.0000	24.42+/-	2.78
V	88	39	10.390+/-	1.039	.6611	28.93+/-	2.89
RB	89	37	2.732+/-	.102	.8788	15.43+/-	.58
TR	89	40	4.191+/-	.367	.9901	39.13+/-	3.43
V	90M	39	14.631+/-	.760	1.0000	37.72+/-	1.96
SR	91	38	6.508+/-	.277	.8393	26.64+/-	1.14
V	91M	39	13.513+/-	1.500	1.0000	34.28+/-	3.80
SR	92	38	2.634+/-	.125	.8807	19.18+/-	.91
V	92	39	12.432+/-	1.089	.9819	35.49+/-	3.11
NB	92M	41	.475+/-	.053	1.0000	3.46+/-	.38
MO	93M	42	1.423+/-	.052	1.0000	30.03+/-	1.10
V	94	39	3.122+/-	.312	.8618	15.26+/-	1.63
TC	94	43	.659+/-	.086	.9943	58.53+/-	7.61

ZR 95	40	12.069+/-	1.207	.8657	33.88+/-	3.39
NB 95M	41	4.248+/-	4.205	1.0000	11.08+/-	10.97
TC 95	43	1.419+/-	.302	.9954	47.92+/-	10.21
NB 96	41	15.293+/-	.487	1.0000	38.56+/-	1.23
TC 96	43	3.537+/-	.489	1.0000	53.05+/-	7.34
ZR 97	40	2.823+/-	.176	.8756	19.06+/-	1.19
NB 98	41	8.915+/-	.418	.7864	26.12+/-	1.22
MO 99	42	23.931+/-	3.484	.6892	43.00+/-	6.26
RH 99M	45	.198+/-	.054	.9919	19.86+/-	5.43
RH100	45	.916+/-	.133	1.0000	34.50+/-	5.02
MO101	42	5.884+/-	.807	.8159	21.17+/-	2.90
TC101	43	30.436+/-	.900	1.0000	76.44+/-	2.26
RH101M	45	3.301+/-	1.245	1.0000	54.02+/-	20.38
TC102	43	20.600+/-	20.390	1.0000	57.24+/-	56.65
RU103	44	34.346+/-	3.936	.5284	46.04+/-	5.28
TC104	43	4.205+/-	.421	.8498	19.22+/-	1.92
RU105	44	11.962+/-	2.320	.8300	30.28+/-	5.87
RH105	45	32.900+/-	3.290	.9682	85.61+/-	8.56
RH106M	45	15.259+/-	.950	1.0000	38.25+/-	2.38
AG106M	47	3.663+/-	.194	1.0000	65.53+/-	3.47
RH107	45	13.782+/-	3.583	.7354	27.61+/-	7.18
RH108B	45	3.469+/-	.347	1.0000	11.97+/-	1.20
AG110M	47	14.467+/-	1.139	1.0000	39.59+/-	3.12
IN110M	49	2.803+/-	.318	1.0000	131.03+/-	14.89
PD111M	46	1.254+/-	.192	.8008	4.04+/-	.62
AG111	47	26.139+/-	2.987	.9829	64.42+/-	7.36
CD111M	48	18.086+/-	.602	1.0000	76.91+/-	2.56
IN111	49	5.028+/-	.503	.9847	97.04+/-	9.70
PD112	46	13.910+/-	13.770	.8591	75.82+/-	75.05
AG112	47	15.323+/-	3.060	1.0000	41.02+/-	8.19
AG113	47	33.020+/-	3.302	.7782	85.57+/-	8.56
IN113M	49	1.779+/-	.188	1.0000	9.70+/-	1.03
CD115	48	2.050+/-	.205	.8960	5.31+/-	.53
CD115M	48	28.338+/-	.559	1.0000	81.98+/-	1.62
SB115	51	1.497+/-	.189	.9660	75.52+/-	9.53
IN116M	49	10.785+/-	1.070	1.0000	27.11+/-	2.69
SB116M	51	3.225+/-	.232	1.0000	69.39+/-	5.00
CD117	48	13.515+/-	1.696	.8620	69.53+/-	8.73
CD117M	48	5.486+/-	1.479	1.0000	32.74+/-	8.83
IN117	49	6.619+/-	.120	1.0000	17.45+/-	.32
SB118M	51	10.283+/-	.838	1.0000	59.37+/-	4.84
TE119M	52	4.369+/-	.058	1.0000	66.70+/-	.88
I 119	53	.255+/-	.124	.9772	42.03+/-	20.34
SB120B	51	8.436+/-	.380	1.0000	24.08+/-	1.08
I 120	53	.917+/-	.312	.9914	53.19+/-	18.12
TE121	52	4.976+/-	.453	.9978	23.28+/-	2.12
TE121M	52	12.965+/-	1.889	1.0000	60.78+/-	8.85
I 121	53	3.840+/-	.414	.9870	89.72+/-	9.67
SB122	51	4.801+/-	.229	1.0000	12.49+/-	.59
XE122	54	.915+/-	.092	.9614	91.16+/-	9.12
XE123	54	2.053+/-	.028	.9617	76.00+/-	1.03
I 124	53	8.616+/-	.796	1.0000	33.80+/-	3.12
XE125	54	8.584+/-	.086	.9880	70.70+/-	.71
CS125	55	1.917+/-	.503	.9704	122.08+/-	32.07
XE127	54	13.201+/-	2.464	.9938	44.36+/-	8.28
CS127	55	4.026+/-	.857	.9662	47.01+/-	10.01
SB128	51	.509+/-	.094	.9947	38.95+/-	7.19
BA128	56	1.431+/-	.238	.9610	58.95+/-	9.81
CS129	55	11.861+/-	.268	.9866	47.07+/-	1.08
BA129	56	1.554+/-	.155	.9571	77.11+/-	2.71
I 130	53	.166+/-	.116	1.0000	1.11+/-	.77
CS130	55	.476+/-	.450	1.0000	2.03+/-	1.35

BA131	56	13.208+/-	.569	.9776	67.30+/-	2.90
BA131M	56	4.068+/-	.488	1.0000	21.20+/-	2.55
LA131	57	2.180+/-	.150	.9659	60.68+/-	4.16
LA132	57	3.595+/-	3.382	.9970	46.99+/-	46.83
LA132M	57	7.063+/-	3.430	1.0000	92.62+/-	44.97
BA133M	56	2.874+/-	.031	1.0000	7.89+/-	.08
BA135M	56	5.701+/-	.570	1.0003	15.21+/-	1.52
CE135	58	2.782+/-	.052	.9671	26.15+/-	.49
CS136	55	3.419+/-	.919	1.0000	39.24+/-	10.55
PR138M	59	2.622+/-	.213	1.0000	19.47+/-	1.59
ND139M	60	1.779+/-	.285	.9526	37.18+/-	5.96
LA140	57	.265+/-	.040	1.0000	1.56+/-	.23
TB152	65	.436+/-	.046	.9957	8.07+/-	.84
TB153	65	1.477+/-	.202	.9961	13.48+/-	1.84
DY155	66	.631+/-	.171	.9854	8.29+/-	2.24
DY157	66	1.258+/-	.126	.9209	5.02+/-	.50
TA177	73	1.331+/-	.483	.9695	3.32+/-	1.21
RE180	75	5.046+/-	2.741	1.0000	22.09+/-	12.00
OS181M	76	2.649+/-	.265	1.0000	26.56+/-	2.66
RE182	75	2.677+/-	.922	.9968	6.95+/-	2.35
RE182M	75	3.321+/-	1.327	1.0000	8.64+/-	3.45
IR186	77	10.676+/-	.844	.9827	33.85+/-	2.68
IR186M	77	4.497+/-	.450	1.0000	14.51+/-	1.45
IR188	77	1.031+/-	.323	1.0000	2.59+/-	.81
AU188	79	.540+/-	.535	.9276	8.06+/-	7.98
AU189	79	1.755+/-	.241	.9289	13.33+/-	1.83
IR190M	77	.397+/-	.222	1.0000	1.43+/-	.80
IR190M	77	.397+/-	.222	1.0000	.95+/-	.53
AU190	79	1.607+/-	1.020	.9388	7.30+/-	4.63
HG190	80	.509+/-	.051	.9323	11.91+/-	1.19
AU191	79	22.134+/-	5.614	.9618	71.02+/-	18.01
HG192	80	4.466+/-	.504	.9257	26.32+/-	2.97
AU193	79	22.810+/-	6.715	.9904	56.65+/-	16.68
HG193M	80	4.073+/-	.126	.9372	15.38+/-	.48
AU194	79	11.029+/-	.592	1.0000	30.15+/-	1.62
AU194	79	11.029+/-	.592	1.0000	70.12+/-	3.76
TL194	81	5.113+/-	.511	.9406	42.23+/-	4.22
TL194M	81	3.575+/-	.285	1.0000	31.39+/-	2.50
AU195	79	31.634+/-	.578	.9936	109.15+/-	1.99
AU195	79	31.634+/-	.578	.9999	82.10+/-	1.50
HG195	80	22.825+/-	5.097	.9445	55.05+/-	12.29
HG195M	80	8.644+/-	.531	1.0000	22.07+/-	1.36
AU196	79	85.639+/-	3.807	1.0000	139.25+/-	6.19
AU196M	79	2.360+/-	.415	1.0000	12.13+/-	2.13
TL196	81	16.573+/-	7.588	.9478	54.29+/-	24.86
TL196M	81	2.695+/-	.270	1.0000	9.32+/-	.93
PB196	82	1.075+/-	.125	.9125	12.87+/-	1.49
PT197M	78	27.431+/-	3.691	1.0000	262.43+/-	35.31
HG197M	80	33.526+/-	6.625	1.0000	99.97+/-	19.75
HG197M	80	33.526+/-	6.625	1.0000	136.41+/-	26.95
TL197	81	16.750+/-	9.197	.9297	42.47+/-	23.32
PB197M	82	11.562+/-	1.462	.8764	68.70+/-	8.69
AU198	79	8.969+/-	.442	1.0000	159.70+/-	7.87
TL198	81	41.754+/-	1.337	.9640	100.91+/-	3.23
TL198M	81	34.662+/-	2.757	1.0000	86.90+/-	6.91
TL198	81	16.688+/-	.844	1.0000	41.84+/-	2.12
PB198	82	14.919+/-	.914	.9053	56.95+/-	3.49
BT198	83	3.323+/-	.187	.9282	59.45+/-	3.34
AU199	79	17.672+/-	5.390	.9961	89.36+/-	27.25
HG199M	80	11.406+/-	7.656	1.0000	73.19+/-	49.13
TL199	81	28.984+/-	5.054	.9143	71.16+/-	12.41
PB199	82	16.469+/-	1.227	.9139	45.98+/-	3.43

AU200M	79	4.823+/-	1.058	1.0000	83.32+/-	18.28
TL200	81	17.521+/-	1.652	.9885	58.04+/-	5.47
PB200	82	32.598+/-	8.852	.9036	75.96+/-	20.63
BI200	83	6.147+/-	.615	.9189	30.46+/-	3.05
TL201	81	7.784+/-	.778	.9579	36.33+/-	3.63
PB201	82	8.077+/-	4.894	.9446	19.35+/-	11.72
BI201	83	1.108+/-	.171	1.0000	3.97+/-	.61
BI201M	83	3.097+/-	.310	.9026	10.03+/-	1.00
BI202	83	3.629+/-	.040	.9349	9.44+/-	.10
PO202	84	1.547+/-	.261	.9775	10.94+/-	1.84
PB203	82	2.846+/-	.254	.9747	10.76+/-	.96
BI204	83	2.324+/-	.595	.9624	5.91+/-	1.51
BI205	83	2.330+/-	.229	.8914	6.73+/-	.66
PO205	84	.877+/-	.030	.8980	2.05+/-	.07

XBL 776-9024

336-MEV AR-40 + AU-197

NUCLIDE A Z	EXPERIMENTAL YIELD(MB)	FRACTION INDEPENDENT	CALCULATED MASS YIELD(MB)
EXPERIMENT 126AU 336-MEV AR-40 + AU-197			
1 123 53	4.220+/-	3.915	.8842
1 124 53	3.513+/-	.101	1.0000
1 126 53	3.188+/-	.373	1.0000
1 128 53	.642+/-	.005	1.0000
1 130 53	.119+/-	.008	1.0000
EXPERIMENT D126AU 336-MEV AR-40 + AU-197			
SB118M 51	3.297+/-	.098	1.0000
SB120B 51	4.352+/-	.460	1.0000
SB122 51	3.590+/-	.067	1.0000
SB124 51	.870+/-	.087	1.0000
SB126 51	.057+/-	.056	1.0000
EXPERIMENT 5H26AU 336-MEV AR-40 + AU-197			
RU 97 44	.372+/-	.020	.9393
RU103 44	9.803+/-	9.705	.6187
RU105 44	5.952+/-	.713	.7944
PT188 78	4.334+/-	.087	.7251
PT189 78	6.268+/-	.660	.6349
PT191 78	3.384+/-	.429	.6004
EXPERIMENT PB26AU 336-MEV AR-40 + AU-197			
IN110M 49	1.053+/-	.136	1.0000
IN111 49	3.311+/-	.271	.9052
IN114M 49	8.192+/-	.729	1.0000
IN116M 49	8.157+/-	1.193	1.0000
BI203 83	2.776+/-	.139	.4967
BI204 83	1.212+/-	.014	.5759
BI205 83	1.586+/-	.074	.3574
EXPERIMENT U26AU 336-MEV AR-40 + AU-197			
NI 65 28	1.966+/-	.127	.8486
NI 66 28	1.205+/-	.120	.8942
ZN 69M 30	1.936+/-	.194	1.0000
ZN 71M 30	1.139+/-	.176	1.0000
ZN 72 30	.722+/-	.058	.9237
RB 82M 37	.865+/-	.086	1.0000
RB 83 37	3.199+/-	.037	.9809
RB 84 37	5.016+/-	.493	1.0000
RB 95 41	7.797+/-	.780	1.0000
RB 96 41	5.501+/-	.802	1.0000
CS127 55	2.213+/-	.089	.8672
CS129 55	5.695+/-	.161	.8424
CS132 55	2.018+/-	.040	1.0000
CS134 55	.721+/-	.033	1.0000
EXPERIMENT LA26AU 336-MEV AR-40 + AU-197			
SC 46 21	2.164+/-	2.142	1.0000

XBL 776-9029

SC 47	21	4.419+/-	.571	1.0000	23.90+/-	3.09
SC 48	21	4.131+/-	.225	1.0000	39.18+/-	2.13

EXPERIMENT TH26AU 336-MEV AR-40 + AU-197

SC 44	21	.089+/-	.088	1.0000	.22+/-	.22
SC 44M	21	.457+/-	.046	1.0000	1.15+/-	.11
SC 46	21	3.381+/-	.107	1.0000	12.15+/-	.39
SC 47	21	7.667+/-	.767	1.0000	41.46+/-	4.15
SC 48	21	3.695+/-	.761	1.0000	35.04+/-	7.22
ZR 89	40	1.321+/-	.132	.9063	7.22+/-	.72
ZR 95	40	5.630+/-	.039	.8096	1.93+/-	.13
ZR 97	40	1.636+/-	.164	.9063	18.96+/-	1.90

EXPERIMENT FI26AU 336-MEV AR-40 + AU-197

TE119M	52	3.077+/-	.329	1.0000	27.14+/-	2.91
TE121	52	2.483+/-	.137	.8557	7.35+/-	.40
TE121M	52	9.725+/-	.973	1.0000	33.67+/-	3.37

EXPERIMENT PB29AU 336-MEV AR-40 + AU-197

PB196	82	.808+/-	.354	.8450	4.94+/-	2.17
PB197M	82	1.037+/-	1.000	.8099	3.71+/-	3.58
PB198	82	2.418+/-	.673	.7330	5.57+/-	1.55
PB199	82	3.068+/-	.855	.6298	5.04+/-	1.40
PB200	82	11.921+/-	1.001	.5804	17.45+/-	1.47
PB201	82	13.972+/-	.663	.5866	23.28+/-	1.11
PB202M	82	3.659+/-	.245	1.0000	13.65+/-	.91
PB203	82	2.054+/-	.078	.7031	8.24+/-	.31
PB204M	82	.055+/-	.006	1.0000	.56+/-	.06

EXPERIMENT AU33AU 336-MEV AR-40 + AU-197

AU190	79	2.740+/-	.102	.7192	6.82+/-	.25
AU191	79	3.016+/-	.273	.7516	6.19+/-	.56
AU192	79	4.032+/-	.212	1.0000	10.11+/-	.53
AU193	79	5.015+/-	.436	.8779	11.82+/-	1.03
AU194	79	11.747+/-	.561	1.0000	39.34+/-	1.88
AU194	79	11.747+/-	.561	1.0000	74.64+/-	3.56
AU195	79	35.618+/-	1.447	.9083	157.55+/-	6.40
AU195	79	35.618+/-	1.447	.9987	92.49+/-	3.76
AU196	79	87.879+/-	5.271	1.0000	143.09+/-	8.58
AU196M	79	3.941+/-	.173	1.0000	32.53+/-	1.43
AU198	79	38.659+/-	2.550	1.0000	87.03+/-	5.74
AU198M	79	.859+/-	.055	1.0000	32.22+/-	2.05
AU200	79	.149+/-	.004	1.0000	46.97+/-	1.32
AU200	79	.149+/-	.004	1.0000	2.51+/-	.07
AU200M	79	.224+/-	.130	1.0000	70.35+/-	40.95
AU200M	79	.224+/-	.130	1.0000	3.76+/-	2.19

EXPERIMENT HG33AU 336-MEV AR-40 + AU-197

HG191	80	3.584+/-	3.189	.8463	20.62+/-	18.35
HG192	80	2.890+/-	.453	.8067	9.85+/-	1.54
HG193	80	1.108+/-	.006	.7483	.25+/-	.01
HG193M	80	4.850+/-	1.295	1.0000	14.83+/-	3.96
HG195M	80	9.014+/-	.355	1.0000	22.86+/-	.90
HG195M	80	8.956+/-	1.056	1.0000	22.71+/-	2.68
HG197M	80	19.147+/-	.081	1.0000	74.31+/-	.31
HG197M	80	19.147+/-	.081	1.0000	78.53+/-	.33
HG197M	80	18.400+/-	1.114	1.0000	71.41+/-	4.32

MG197M 80	18.400+/-	1.114	1.0000	75.47+/-	4.57
MG199M 80	6.673+/-	.843	1.0000	73.12+/-	9.24
MG199M 80	6.673+/-	.843	1.0000	10.12+/-	1.28

EXPERIMENT 0538AU 336-REV AR-40 + AU-197

OS180 76	2.024+/-	.003	.8982	19.90+/-	.03
OS181M 76	.445+/-	.016	1.0000	2.69+/-	.10
OS162 76	3.449+/-	.352	.7985	10.68+/-	1.09
OS183 76	3.048+/-	.121	.7829	6.93+/-	.28
OS183M 76	1.446+/-	.427	.7810	3.28+/-	.97
OS185 76	1.920+/-	.004	.9240	4.58+/-	.01
OS190M 76	1.000+/-	.200	1.0000	27.94+/-	5.59
OS190M 76	1.000+/-	.200	1.0000	1.93+/-	.39

EXPERIMENT PT40AU 336-REV AR-40 + AU-197

RH 99M 45	.263+/-	.026	1.0000	12.11+/-	1.21
RH100 45	.686+/-	.092	1.0000	13.25+/-	1.78
RH105 45	1.017+/-	.138	.8447	2.16+/-	.29
RH106M 45	4.284+/-	.290	1.0000	11.33+/-	.77
IR183 77	4.541+/-	.454	.8837	33.08+/-	3.31
IR184 77	6.963+/-	.696	.8547	28.96+/-	2.90
IR186 77	1.636+/-	.164	1.0000	4.39+/-	.44
IR187 77	13.150+/-	1.194	.8282	27.30+/-	2.48
PT187 78	2.159+/-	.146	.7945	6.94+/-	.47
PT188 78	4.967+/-	.333	.7262	10.74+/-	.72
PT189 78	4.744+/-	1.666	.6589	7.99+/-	2.80
IR190M 77	9.195+/-	.739	1.0000	21.89+/-	1.75
PT191 78	5.291+/-	.728	.6857	10.81+/-	1.49

EXPERIMENT 63AU 336-REV AR-40 + AU-197

MG 28 12	1.415+/-	.113	.9642	174.96+/-	13.92
S 38 16	18.087+/-	.500	.9610	1753.10+/-	48.43
CL 38 17	13.117+/-	1.130	1.0000	143.92+/-	12.40
CL 39 17	45.988+/-	.548	.9298	992.18+/-	11.82
AR 41 18	89.209+/-	8.921	.9137	1224.10+/-	122.41
K 42 19	9.969+/-	.997	1.0000	56.95+/-	5.70
K 43 19	7.112+/-	.239	.8942	64.81+/-	2.18
SC 44 21	54.330+/-	37.508	1.0000	136.48+/-	94.23
SC 44M 21	1.083+/-	.296	1.0000	2.72+/-	.74
SC 46 21	3.257+/-	.303	1.0000	11.71+/-	1.09
CA 47 20	1.806+/-	.181	.9380	52.20+/-	5.22
SC 47 21	14.996+/-	6.954	1.0000	81.10+/-	37.61
SC 48 21	3.436+/-	.328	1.0000	32.59+/-	3.11
CR 48 24	6.615+/-	.661	.8598	36.37+/-	3.64
MN 54 25	1.059+/-	.723	1.0000	2.66+/-	1.81
MN 56 25	3.908+/-	.051	.7656	10.02+/-	.13
CO 58 27	.749+/-	.172	1.0000	2.08+/-	.48
FE 59 26	3.804+/-	.199	.7944	11.74+/-	.61
CO 60 27	2.867+/-	.141	1.0000	7.58+/-	.37
NI 65 28	1.925+/-	.192	.8486	9.33+/-	.93
CU 67 29	5.918+/-	.592	.8164	21.38+/-	2.14
ZN 69M 30	2.346+/-	.265	1.0000	8.43+/-	.95
GE 69 32	1.504+/-	.329	.8422	6.16+/-	1.35
ZN 71M 30	1.152+/-	.075	1.0000	10.93+/-	.71
ZN 72 30	.279+/-	.058	.9237	5.00+/-	1.05
GA 72 31	3.989+/-	.526	1.0000	16.87+/-	2.22
AS 74 33	2.470+/-	.313	1.0000	6.31+/-	.80
SE 75 34	1.248+/-	.094	.8651	3.74+/-	.28
BR 76 35	2.706+/-	.591	.9861	18.13+/-	3.96

GE 77	32	.400+/-	.099	.9205	6.55+/-	1.62
BR 77	35	.865+/-	.086	.8735	3.19+/-	.32
AS 78	33	3.899+/-	.390	.9024	22.55+/-	2.26
BR 82	35	4.686+/-	.130	1.0000	18.19+/-	.50
RB 82M	37	7.229+/-	3.499	1.0000	31.93+/-	15.45
RB 83	37	3.479+/-	1.014	.9859	10.78+/-	3.14
RB 84	37	4.897+/-	.490	1.0000	12.77+/-	1.28
KR 85M	36	1.592+/-	.148	.8252	6.09+/-	.56
SR 85M	38	10.224+/-	2.647	1.0000	38.10+/-	9.86
Y 86	39	.928+/-	.094	1.0000	7.16+/-	.73
Y 87M	39	4.989+/-	.320	.8930	20.63+/-	1.33
Y 87	39	.621+/-	.027	.8963	2.58+/-	.11
Y 88	39	5.673+/-	.277	.9890	18.18+/-	.89
ZR 89	40	2.250+/-	.225	.9147	12.41+/-	1.24
Y 90M	39	5.480+/-	.424	1.0000	13.77+/-	1.06
SR 91	38	3.665+/-	.755	.8712	23.14+/-	4.77
Y 91M	39	4.853+/-	.845	1.0000	13.51+/-	2.35
SR 92	38	1.356+/-	.074	.9100	17.08+/-	.93
Y 92	39	5.726+/-	2.931	.8942	18.40+/-	9.42
NB 92M	41	.238+/-	.024	1.0000	1.16+/-	.12
MO 93M	42	.757+/-	.076	1.0000	8.93+/-	.89
NB 96	41	5.601+/-	.505	1.0000	15.29+/-	1.38
TC 96	43	1.672+/-	.097	1.0000	14.74+/-	.85
ZR 97	40	1.500+/-	.019	.9063	17.37+/-	.22
NB 98	41	2.674+/-	.493	.8363	11.47+/-	2.11
MO 99	42	10.222+/-	1.160	.7281	22.17+/-	2.52
RH100	45	.576+/-	.164	1.0000	11.14+/-	3.16
TC101	43	11.541+/-	8.327	1.0000	30.98+/-	22.35
RH101M	45	1.089+/-	.311	1.0000	10.30+/-	2.94
RU103	44	16.480+/-	2.821	.6172	25.80+/-	4.42
TC104	43	2.451+/-	.245	.8806	17.82+/-	1.78
RU105	44	5.924+/-	2.533	.8001	18.40+/-	7.87
RH105	45	14.161+/-	1.372	.8281	29.46+/-	2.85
AG105	47	1.290+/-	.021	.9492	25.86+/-	.43
RH106M	45	5.024+/-	.617	1.0000	13.28+/-	1.63
AG106M	47	2.191+/-	.258	1.0000	22.27+/-	2.62
AG110M	47	6.239+/-	.295	1.0000	15.73+/-	.74
IN110M	49	1.252+/-	.136	1.0000	28.96+/-	3.15
PD111M	46	.557+/-	.551	1.0000	3.18+/-	3.15
CD111M	48	5.896+/-	.321	1.0000	19.11+/-	1.04
IN111	49	3.351+/-	.209	.9175	33.64+/-	2.10
SN113	50	2.635+/-	.408	.9201	39.44+/-	6.11
IN114M	49	7.362+/-	.736	1.0000	21.38+/-	2.14
IN116M	49	4.870+/-	1.806	1.0000	12.56+/-	4.66
SB116M	51	1.763+/-	.274	1.0000	20.81+/-	3.23
CD117	48	5.397+/-	.540	.8902	45.54+/-	4.55
IN117	49	4.259+/-	.772	1.0000	13.03+/-	2.36
SB118M	51	5.726+/-	.389	1.0000	23.15+/-	1.57
TE119M	52	3.218+/-	.148	1.0000	28.39+/-	1.31
SB120B	51	6.201+/-	.188	1.0000	15.84+/-	.48
I 120	53	.536+/-	.051	.9430	14.09+/-	1.33
TE121M	52	6.186+/-	3.754	1.0000	21.42+/-	13.00
SB122	51	3.526+/-	.353	1.0000	10.50+/-	1.05
XE122	54	.664+/-	.438	.9475	28.95+/-	19.08
TE123M	52	6.008+/-	4.617	1.0000	15.06+/-	11.58
SB124	51	.781+/-	.036	1.0000	5.01+/-	.23
I 124	53	8.994+/-	.971	1.0000	27.49+/-	2.97
I 126	53	3.192+/-	.624	1.0000	8.09+/-	1.58
XE127	54	13.256+/-	.827	.9216	33.98+/-	2.12
BA128	56	2.328+/-	.041	.9285	45.65+/-	.80
CS129	55	5.662+/-	.646	.8693	15.48+/-	1.77
BA129	56	1.036+/-	.104	.8968	9.44+/-	.94

I 130	53	1.530+/-	.266	1.0000	16.77+/-	2.92
BA131	56	17.332+/-	2.479	.8466	54.68+/-	7.62
BA131M	56	2.691+/-	.816	1.0000	10.03+/-	3.04
LA131	57	2.602+/-	.320	.9145	35.63+/-	4.38
LA132	57	5.945+/-	.603	.9601	44.03+/-	4.46
BA133	56	11.778+/-	.118	.8460	25.12+/-	.25
BA133M	56	3.381+/-	.471	1.0000	8.52+/-	1.19
CE133	58	.922+/-	.237	.9297	19.83+/-	5.10
CS134	55	.351+/-	.100	1.0000	2.00+/-	.57
BA135M	56	5.733+/-	.573	1.0000	18.04+/-	1.80
CE135	58	6.950+/-	.922	.8700	36.49+/-	4.84
CS136	55	.315+/-	.008	1.0000	6.67+/-	.16
CE137M	58	3.791+/-	.467	1.0000	11.01+/-	1.36
PR138M	59	4.300+/-	.314	1.0000	20.92+/-	1.53
CE139	58	12.220+/-	.689	.7969	25.12+/-	1.42
ND139M	60	3.101+/-	.501	1.0000	36.60+/-	5.91
LA140	57	1.779+/-	.178	1.0000	16.86+/-	1.69
CE141	58	1.683+/-	.187	.9368	6.66+/-	.74
PM143	61	4.908+/-	.490	.8435	21.19+/-	2.12
PM144	61	4.301+/-	.303	1.0000	14.89+/-	1.05
PM146	61	1.476+/-	.169	1.0000	3.70+/-	.42
EU146	63	2.282+/-	.974	1.0000	44.10+/-	18.83
EU147	63	3.733+/-	.500	.9979	35.24+/-	4.72
PM148M	61	1.029+/-	.142	1.0000	3.45+/-	.47
EU148	63	3.487+/-	.211	1.0000	18.82+/-	1.14
EU149	63	8.147+/-	2.103	.9983	29.19+/-	7.53
GD149	64	3.047+/-	.282	.9738	40.96+/-	3.80
GD151	64	3.176+/-	1.341	.9838	13.80+/-	5.83
TB151	65	2.157+/-	.864	.9337	42.55+/-	17.04
TB152	65	1.843+/-	.263	.9528	17.86+/-	2.55
GD153	64	4.943+/-	.161	.9869	12.72+/-	.41
TB153	65	2.028+/-	1.043	.9522	11.01+/-	5.66
TB154	65	2.832+/-	.450	1.0000	10.55+/-	1.68
TB155	65	6.373+/-	1.125	.9504	17.20+/-	3.04
DY155	66	4.588+/-	.459	.9044	32.01+/-	3.20
TB156	65	1.669+/-	.102	1.0000	4.21+/-	.46
DY157	66	5.631+/-	.563	.7676	14.01+/-	1.40
HD159	67	4.225+/-	.833	1.0000	16.38+/-	3.23
ER160	68	2.219+/-	.222	.8804	16.10+/-	1.61
TM163	69	2.190+/-	.219	.8636	12.10+/-	1.21
TM166	69	4.746+/-	1.188	1.0000	12.13+/-	3.03
YB166	70	.789+/-	.068	.8362	3.38+/-	.29
TM167	69	4.281+/-	1.751	.5435	5.94+/-	2.43
YB167	70	4.045+/-	1.712	1.0000	14.00+/-	5.93
TM168	69	.890+/-	.201	1.0000	2.65+/-	.60
YB169	70	6.000+/-	3.305	.9736	14.65+/-	8.07
LU169	71	9.665+/-	2.381	.8852	36.13+/-	8.90
LU170	71	6.000+/-	2.788	.9624	17.65+/-	8.20
HF170	72	1.569+/-	.515	.8897	13.21+/-	4.33
LU171	71	3.263+/-	.108	.9504	8.00+/-	.26
HF172	72	7.723+/-	1.213	.8257	22.89+/-	3.60
LU173	71	5.413+/-	.298	.9245	14.54+/-	.80
HF173	72	4.507+/-	.564	.8810	11.04+/-	1.38
HF175	72	4.701+/-	2.250	.8823	10.97+/-	5.25
TA176	73	5.123+/-	1.344	.8188	10.94+/-	2.87
M 177	74	2.672+/-	.267	.7965	7.93+/-	.79
RE181	75	4.054+/-	1.135	.7947	8.52+/-	2.38
TA182	73	1.312+/-	1.299	1.0000	27.77+/-	27.49
RE182	75	8.555+/-	1.419	.9525	20.47+/-	3.40
OS182	76	2.333+/-	1.578	.8084	7.31+/-	4.95
RE183	75	5.166+/-	.341	.8927	12.83+/-	.85
OS183G	76	3.133+/-	3.102	.7853	7.15+/-	7.08

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OS183M	76	1.214+/-	.293	.7845	2.77+/-	.67
RE184	75	3.561+/-	.171	1.0000	12.79+/-	.61
IR184	77	4.077+/-	.586	.8417	16.70+/-	2.40
OS185	76	4.635+/-	.217	.9159	10.95+/-	.51
IR186	77	2.797+/-	1.060	.8281	6.22+/-	2.36
IR186M	77	1.786+/-	.265	1.0000	4.79+/-	.71
PT186	78	1.124+/-	.125	.8643	6.22+/-	.69
IR187	77	13.925+/-	5.538	.7620	26.60+/-	10.58
IR188	77	1.671+/-	.658	1.0000	4.56+/-	1.80
PT188	78	4.944+/-	.062	.7347	10.60+/-	.14
AU188	79	2.667+/-	.764	.8851	20.83+/-	5.97
PT189	78	5.992+/-	1.586	.6698	10.25+/-	2.71
IR190	77	.404+/-	.194	1.0000	2.07+/-	.99
IR190	77	.404+/-	.194	1.0000	.96+/-	.46
IR190M	77	.308+/-	.049	1.0000	1.58+/-	.25
IR190M	77	.308+/-	.049	1.0000	.73+/-	.12
AU190	79	7.704+/-	1.509	.7732	20.63+/-	4.04
AU191	79	15.692+/-	.323	.7464	31.97+/-	.66
HG191	80	7.381+/-	.738	.8664	43.48+/-	4.35
IR192	77	.261+/-	.035	1.0000	4.64+/-	.62
IN192	77	.261+/-	.035	1.0000	.42+/-	.06
HG192	80	5.050+/-	.505	.8163	17.41+/-	1.74
AU193	79	14.877+/-	2.268	.8687	34.69+/-	5.29
HG193M	80	5.145+/-	.366	.7600	11.95+/-	.85
IR194M	77	.331+/-	.045	1.0000	1.91+/-	.26
IR194M	77	.331+/-	.045	1.0000	37.58+/-	5.14
AU194	79	13.436+/-	1.005	1.0000	44.99+/-	3.36
AU194	79	13.436+/-	1.005	1.0000	85.37+/-	6.38
TL194	81	2.926+/-	.293	.8429	12.32+/-	1.33
IR195M	77	4.295+/-	.430	.9947	87.49+/-	8.75
AU195	79	44.070+/-	4.407	.9001	193.18+/-	19.32
AU195	79	44.070+/-	4.407	.9985	114.42+/-	11.44
HG195M	80	9.638+/-	3.599	1.0000	24.44+/-	9.13
AU196	79	80.887+/-	18.463	1.0000	131.71+/-	30.06
AU196M	79	7.120+/-	2.466	1.0000	58.76+/-	20.35
TL196	81	12.286+/-	.887	.7257	24.80+/-	1.79
HG197M	80	18.444+/-	1.150	1.0000	71.59+/-	4.46
HG197M	80	18.444+/-	1.150	1.0000	75.65+/-	4.72
TL197	81	14.710+/-	1.471	.6418	23.71+/-	2.37
PB197M	82	1.946+/-	1.927	.8163	7.02+/-	6.95
AU198	79	37.318+/-	2.020	1.0000	84.02+/-	4.55
AU198M	79	2.268+/-	.650	1.0000	85.09+/-	24.38
TL198	81	17.878+/-	.802	.6759	31.94+/-	1.43
TL198M	81	15.447+/-	1.754	1.0000	40.84+/-	4.64
PB198	82	5.728+/-	1.075	.7518	13.54+/-	2.54
AU199	79	20.225+/-	3.443	.9848	99.60+/-	16.95
HG199M	80	6.160+/-	6.098	1.0000	67.51+/-	66.83
HG199M	80	6.160+/-	6.098	1.0000	9.34+/-	9.25
TL199	81	34.208+/-	6.141	.4925	54.63+/-	9.81
PB199	82	3.000+/-	2.492	.6681	5.23+/-	4.34
PB199	82	6.368+/-	2.081	.6549	10.88+/-	3.55
TL200	81	18.902+/-	1.732	.8346	73.14+/-	6.70
PB200	82	10.928+/-	1.132	.5970	16.30+/-	1.70
B1200	83	1.583+/-	1.433	.7871	4.64+/-	4.21
TL201	81	6.312+/-	.508	.5770	28.13+/-	2.26
PB201	82	6.515+/-	2.425	.5938	10.99+/-	4.09
B1201M	83	2.435+/-	.474	.7097	4.91+/-	.96
TL202	81	.201+/-	.030	1.0000	3.02+/-	.44
PB202M	82	2.032+/-	.449	1.0000	7.58+/-	1.68
B1202	83	13.034+/-	3.596	.6453	21.20+/-	5.85
PB203	82	3.104+/-	.381	.6978	12.36+/-	1.52
B1203	83	.822+/-	.082	.5348	1.15+/-	.11

B1204	83	1.099+/-	.078	.6459	2.23+/-	.16
B1205	83	1.395+/-	.026	.4129	2.55+/-	.05

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705-MEV KR-84 + AU-197

NUCLIDE A Z	EXPERIMENTAL YIELD(MB)	FRACTION INDEPENDENT	CALCULATED MASS YIELD(MB)
EXPERIMENT 145AU 705-MEV KR-84 + AU-197			
1 119 53	1.934+/- .193	.9014	37.26+/- 3.72
1 120 53	1.411+/- .141	.8912	12.50+/- 1.25
1 121 53	3.970+/- .397	.8528	18.53+/- 1.85
1 123 53	3.858+/- .386	.8301	8.80+/- .88
1 124 53	2.534+/- .657	1.0000	6.35+/- 1.65
1 126 53	1.921+/- .034	1.0000	6.64+/- .12
EXPERIMENT 0545AU 705-MEV KR-84 + AU-197			
05181M 76	2.184+/- .278	1.0000	5.86+/- .75
05182 76	14.520+/- 1.200	.3435	16.93+/- 1.40
05183 76	8.209+/- .725	.2946	12.29+/- 1.09
05183M 76	4.500+/- .800	.2923	6.68+/- 1.19
05185 76	5.290+/- .100	.5016	50.09+/- .95
EXPERIMENT PT45AU 705-MEV KR-84 + AU-197			
A5 71 33	.747+/- .036	.9026	8.02+/- .39
A5 72 33	2.584+/- .258	1.0000	16.21+/- 1.62
A5 74 33	12.386+/- 7.400	1.0000	35.80+/- 21.39
A5 76 33	23.380+/- 5.240	1.0000	61.06+/- 13.69
A5 78 33	22.900+/- .970	.8673	91.92+/- 3.89
IR183 77	4.002+/- .400	.4886	4.99+/- .50
IR184 77	16.790+/- 3.060	.3900	19.64+/- 3.58
IR185 77	12.065+/- 3.138	.3641	18.33+/- 4.77
PT185B 78	5.249+/- .525	.5550	7.30+/- .73
IR186 77	14.560+/- .600	.3370	33.70+/- 1.39
IR186M 77	7.620+/- 7.500	1.0000	52.33+/- 51.51
PT186 78	9.269+/- .927	.4332	10.99+/- 1.10
IR187 77	24.980+/- .760	.2221	74.22+/- 2.26
PT188 78	24.060+/- 8.700	.2130	27.73+/- 10.03
PT189 78	45.330+/- 4.530	.1420	63.00+/- 6.30
IR190 77	13.070+/- 12.780	1.0000	28.45+/- 27.82
IR190M 77	6.679+/- 1.980	1.0000	14.54+/- 4.31
IR195M 77	23.570+/- 2.360	1.0000	523.16+/- 52.38
PT195M 78	.584+/- .577	1.0000	1.09+/- 1.07
EXPERIMENT D150AU 705-MEV KR-84 + AU-197			
TC 94 43	1.791+/- 1.780	.4915	33.14+/- 32.94
TC 95 43	4.621+/- .462	.9370	68.22+/- 6.82
TC 96 43	6.559+/- .555	1.0000	51.19+/- 4.33
SB117 51	5.772+/- 5.600	.4399	9.46+/- 9.18
SB118M 51	3.124+/- .096	1.0000	8.79+/- .27
SB120B 51	3.170+/- .102	1.0000	8.42+/- .27
SB122 51	2.229+/- .033	1.0000	10.96+/- .16
SB124 51	1.110+/- .061	1.0000	19.81+/- 1.09
HG191 80	10.986+/- 1.793	.3863	11.89+/- 1.94
HG192 80	30.026+/- 5.936	.3007	33.37+/- 6.60
HG193M 80	15.435+/- 1.661	1.0000	89.13+/- 9.59
HG193M 80	15.512+/- 11.899	1.0000	89.57+/- 68.71
HG195M 80	21.370+/- 5.936	1.0000	498.82+/- 129.21
HG195M 80	15.012+/- 3.690	1.0000	350.41+/- 86.12

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MG197	80	113.359+/-	22.120	.9873	452.81+/-	88.36
MG197M	80	33.319+/-	5.391	1.0000	134.80+/-	21.81
MG199M	80	11.981+/-	1.198	1.0070	18.21+/-	1.82

EXPERIMENT 5H50AU 705-MEV KR-84 + AU-197

IR184	77	11.010+/-	1.580	.4156	13.73+/-	1.97
IR185	77	11.038+/-	.462	.3432	15.81+/-	.66
IR185	77	14.161+/-	1.555	.3432	20.26+/-	2.23
IR186	77	14.651+/-	4.829	1.0000	100.62+/-	33.17
IR186M	77	10.162+/-	9.600	1.0000	69.79+/-	65.93
IR187	77	23.466+/-	1.502	.1881	59.03+/-	3.78
IR188	77	3.510+/-	1.550	1.0000	108.24+/-	47.78
PT188	78	23.292+/-	1.209	.2121	26.73+/-	1.39
PT189	78	52.824+/-	9.153	.1289	66.63+/-	11.54
IR190	77	8.411+/-	.956	1.0000	18.31+/-	2.08
IR190M	77	2.527+/-	.667	1.0000	5.50+/-	1.45
PT191	78	23.062+/-	1.727	.0717	87.55+/-	6.57
PT195M	78	11.910+/-	.161	1.0000	22.16+/-	.30

EXPERIMENT PB50AU 705-MEV KR-84 + AU-197

IN109	49	1.119+/-	.112	.9306	27.69+/-	2.77
IN110M	49	1.608+/-	.577	1.0000	19.07+/-	6.84
IN111	49	5.877+/-	.170	.8647	31.80+/-	.92
IN114M	49	7.607+/-	1.239	1.0000	19.21+/-	3.13
PB197	82	17.870+/-	6.955	.2927	20.27+/-	7.89
PB198	82	14.837+/-	1.212	.1926	17.66+/-	1.44
PB199	82	17.640+/-	1.421	.1151	23.69+/-	1.91
PB200	82	19.468+/-	1.660	.0711	36.06+/-	3.07
PB201	82	9.838+/-	.814	.0529	35.87+/-	2.97
B1201	83	2.482+/-	2.450	.1267	2.72+/-	2.69
B1201M	83	1.590+/-	.159	.1104	1.52+/-	.15
B1202	83	17.089+/-	1.520	.0655	20.11+/-	1.79
B1203	83	4.833+/-	1.015	.0423	9.02+/-	1.89
B1204	83	1.636+/-	.231	.0411	8.62+/-	1.22
B1205	83	3.848+/-	.136	.0146	24.82+/-	.88

EXPERIMENT U50AU 705-MEV KR-84 + AU-197

MG 28	12	.581+/-	.051	.8858	4.58+/-	.40
V 48	23	.144+/-	.013	.9826	.73+/-	.06
MN 54	25	1.376+/-	1.350	1.0000	4.54+/-	4.45
MN 56	25	4.396+/-	.129	.5878	6.50+/-	.19
CO 58	27	1.110+/-	.111	1.0000	5.09+/-	.51
CO 60	27	1.702+/-	.252	1.0000	4.43+/-	.66
NI 65	28	4.535+/-	.063	.7641	11.71+/-	.16
ZN 65	30	2.101+/-	.153	.8417	9.40+/-	.68
NI 66	28	2.418+/-	.242	.8345	10.19+/-	1.02
CU 67	29	6.905+/-	1.405	.7267	15.01+/-	3.05
ZN 69M	30	5.300+/-	.530	1.0000	14.48+/-	1.45
ZN 71M	30	2.771+/-	.473	1.0000	14.90+/-	2.54
ZN 72	30	1.928+/-	.695	.8912	16.68+/-	6.01
RB 31	37	6.209+/-	.054	.8891	55.04+/-	.48
RB 82M	37	11.328+/-	.994	1.0000	62.13+/-	5.45
RB 83	37	24.903+/-	.257	.9808	87.20+/-	.96
SR 83	38	3.418+/-	.032	.9091	42.41+/-	.40
RB 84	37	32.838+/-	13.965	1.0000	90.31+/-	38.41
SR 87M	38	.817+/-	.082	1.0000	2.09+/-	.21
SR 91	38	9.108+/-	.647	.8692	56.02+/-	3.99
SR 92	38	4.639+/-	.464	.9103	58.77+/-	5.88
CS127	55	5.182+/-	1.175	.7614	13.49+/-	3.06

BA128	56	1.993+/-	.136	.8635	11.14+/-	.76
CS129	55	7.966+/-	.693	.6811	13.61+/-	1.18
BA129	56	3.589+/-	.359	.8032	11.54+/-	1.15
BA131	56	11.117+/-	2.273	.6882	19.38+/-	3.96
CS132	55	.920+/-	.008	1.0000	5.13+/-	.05

EXPERIMENT LA50AU 705-MEV KR-84 + AU-197

Y	86	39	10.120+/-	.670	1.0000	92.74+/-	6.14
Y	87	39	7.242+/-	1.008	1.0000	37.29+/-	5.19
Y	87M	39	19.309+/-	.927	1.0000	99.42+/-	4.78
Y	88	39	27.554+/-	1.897	.7673	72.38+/-	4.94
Y	90M	39	22.554+/-	.289	1.0000	56.56+/-	.72
Y	91M	39	22.708+/-	22.461	1.0000	62.74+/-	62.06
Y	92	39	26.972+/-	2.684	.7791	75.70+/-	7.53
LA132	57		5.090+/-	1.832	.8980	15.03+/-	5.41
CE132	58		1.713+/-	.171	.9001	17.45+/-	1.74
CE133	58		1.277+/-	.128	.8543	6.59+/-	.66
CE135	58		4.067+/-	.946	.7275	8.43+/-	1.96
PR138M	59		3.390+/-	.405	1.0000	8.82+/-	1.05
CE139	58		5.986+/-	.037	.5041	14.42+/-	.09
ND139M	60		.769+/-	.058	1.0000	2.80+/-	.21
PM144	61		2.234+/-	.362	1.0000	5.70+/-	.92
EU146	63		1.755+/-	.212	.8218	5.91+/-	.72
EU147	63		3.709+/-	1.023	.9834	10.83+/-	2.99
GD147	64		2.510+/-	.811	.9088	19.99+/-	6.45
PM148M	61		1.535+/-	.349	1.0000	20.46+/-	4.66
EU148	63		1.988+/-	.245	1.0000	5.06+/-	.62
GD149	64		5.177+/-	.618	.9080	15.74+/-	1.88
TB151	65		5.474+/-	2.313	.8085	17.27+/-	7.30
TB152	65		3.981+/-	.259	.8362	9.60+/-	.63
GD153	64		5.505+/-	.551	.9378	19.06+/-	1.91
TB153	65		5.967+/-	1.351	.8658	13.04+/-	2.95
TB154M	65		.413+/-	.041	1.0000	1.08+/-	.11
TB155	65		.932+/-	.511	.7870	2.35+/-	1.29
DY155	66		6.154+/-	.615	.7052	11.38+/-	1.14
TB156	65		1.121+/-	.197	1.0000	5.21+/-	.92
DY157	66		12.114+/-	1.211	.4308	14.98+/-	1.50
ER158	68		6.006+/-	.601	.8168	21.76+/-	2.18
ER160	68		7.989+/-	1.976	.6428	13.27+/-	3.28
ER161	68		10.034+/-	9.934	.5504	14.03+/-	13.89
TM163	69		9.005+/-	1.772	.5838	13.18+/-	2.59
TM165	69		12.003+/-	8.841	.3405	14.15+/-	10.42
YB166	70		12.268+/-	.919	.5106	16.06+/-	1.20
TM167	69		15.757+/-	1.576	.1426	21.06+/-	2.11
LU169	71		10.808+/-	.594	.5597	16.74+/-	.92
HF170	72		24.685+/-	7.303	.6150	38.45+/-	11.38
LU171	71		9.485+/-	1.133	.6941	36.75+/-	4.39
HF171	72		9.734+/-	.268	.4949	12.51+/-	.34
LU172	71		1.923+/-	.084	1.0000	19.62+/-	.85
HF172	72		20.136+/-	19.935	.3920	24.86+/-	24.61
HF173	72		8.551+/-	.920	.4168	16.11+/-	1.73
HF175	72		2.582+/-	.258	.3356	13.37+/-	1.34

EXPERIMENT 68AU 705-MEV KR-84 + AU-197

SC	46	21	.741+/-	.041	1.0000	1.86+/-	.10
CA	47	20	.654+/-	.013	.8622	3.70+/-	.08
SC	48	21	.968+/-	.223	1.0000	3.34+/-	.77
MN	54	25	1.419+/-	.145	1.0000	4.68+/-	.48
MN	56	25	3.702+/-	.370	.6011	5.60+/-	.56
FE	59	26	3.356+/-	.131	.6594	5.82+/-	.23

ZN 65 30	2.190+/-	.133	.8515	9.91+/-	.60
GE 69 32	2.006+/-	1.205	.8928	15.77+/-	9.48
ZN 71M 30	3.497+/-	.379	1.0000	18.80+/-	2.04
AS 71 33	.617+/-	.062	.9047	6.64+/-	.66
ZN 72 30	1.488+/-	.933	.8912	12.88+/-	8.07
GA 72 31	12.395+/-	2.168	1.0000	38.27+/-	6.69
AS 72 33	14.246+/-	4.597	1.0000	89.35+/-	28.83
SE 73 34	3.552+/-	1.635	.9178	54.08+/-	24.89
AS 74 33	12.377+/-	1.258	1.0000	35.77+/-	3.64
GE 75 32	33.217+/-	3.322	.7842	95.87+/-	9.59
SE 75 34	8.418+/-	1.572	.8905	35.32+/-	6.60
BR 77 35	7.790+/-	7.712	.8976	40.95+/-	40.54
AS 78 33	32.946+/-	4.705	.8659	132.02+/-	18.85
RB 81 37	3.418+/-	.342	.9042	30.81+/-	3.08
BR 82 35	67.544+/-	1.363	1.0000	224.05+/-	4.52
RB 82M 37	14.001+/-	2.378	1.0000	76.79+/-	13.04
SE 83 34	6.485+/-	.649	.9330	155.95+/-	15.60
RB 83 37	27.395+/-	.689	.9866	96.49+/-	2.43
SR 83 38	2.772+/-	.277	.9125	34.53+/-	3.45
BR 84 35	6.991+/-	1.536	.8833	53.02+/-	11.65
RB 84 37	38.772+/-	3.986	1.0000	106.63+/-	10.96
RB 84M 37	18.580+/-	2.459	1.0000	51.10+/-	6.76
KR 85M 36	38.897+/-	.522	.8038	126.61+/-	1.70
SR 85 38	23.328+/-	2.333	.9422	92.73+/-	9.27
Y 85M 39	3.260+/-	.258	1.0000	62.92+/-	4.98
Y 86 39	17.633+/-	5.780	1.0000	161.59+/-	52.97
KR 87 36	5.190+/-	.519	.9059	59.56+/-	5.96
Y 87 39	3.091+/-	.141	1.0000	15.92+/-	.72
Y 87M 39	24.367+/-	2.310	.8983	112.70+/-	10.69
Y 87M 39	16.961+/-	6.423	.8983	78.45+/-	29.71
Y 88 39	29.432+/-	3.002	.6034	60.79+/-	6.20
ZR 88 40	7.396+/-	.740	.9113	83.78+/-	8.38
ZR 89 40	12.869+/-	1.287	.9135	76.28+/-	1.63
Y 90M 39	16.486+/-	.826	1.0000	41.34+/-	2.07
NB 90 41	6.012+/-	.465	.9794	102.55+/-	7.94
SR 91 38	9.684+/-	.399	.8693	59.62+/-	2.45
SR 92 38	3.561+/-	.281	.9103	45.12+/-	3.56
Y 92 39	12.530+/-	12.400	.8841	39.90+/-	39.49
NB 92M 41	.592+/-	.132	1.0000	2.87+/-	.64
MD 93M 42	4.323+/-	.149	1.0000	49.07+/-	1.69
TC 94 43	2.132+/-	.144	.9552	76.67+/-	5.18
ZR 95 40	12.429+/-	.138	.8273	46.30+/-	.52
TC 95 43	4.849+/-	.891	.9504	72.61+/-	13.34
NB 96 41	12.903+/-	.602	1.0000	36.52+/-	1.70
TC 96 43	6.051+/-	.265	1.0000	47.23+/-	2.07
ZR 97 40	3.518+/-	.188	.9145	49.31+/-	2.64
RU 97 44	1.528+/-	.727	.9403	32.45+/-	15.44
MD 99 42	16.234+/-	1.923	.7565	39.99+/-	4.74
RH 99M 45	.907+/-	.082	.9479	28.76+/-	2.59
RH101 45	2.291+/-	.278	.9755	16.16+/-	1.96
RH101M 45	3.501+/-	1.249	1.0000	25.32+/-	9.03
RH102M 45	5.827+/-	4.856	1.0000	25.23+/-	21.02
RU103 44	22.547+/-	1.351	.6728	40.64+/-	2.44
RU105 44	10.595+/-	1.897	.8387	44.98+/-	8.05
RU105 45	17.958+/-	1.380	.8526	39.04+/-	3.00
AG105 47	4.282+/-	.365	.9321	51.89+/-	4.43
RU106 44	4.919+/-	1.094	.8861	39.03+/-	8.68
RH106M 45	9.814+/-	8.642	1.0000	29.38+/-	25.87
AG106M 47	4.427+/-	.536	1.0000	29.74+/-	3.60
AG110M 47	5.763+/-	.113	1.0000	14.86+/-	.29
IN110M 49	2.510+/-	.465	1.0000	29.76+/-	5.52
PD111M 46	3.854+/-	1.838	1.0000	37.52+/-	17.89

IN111	49	5.735+/-	2.516	.8804	31.59+/-	13.86
IN114M	49	4.631+/-	1.559	1.0000	11.69+/-	3.94
SB115	51	2.208+/-	.280	.8978	21.49+/-	2.72
IN116M	49	3.926+/-	.189	1.0000	12.56+/-	.60
SB116M	51	2.415+/-	2.393	1.0000	14.11+/-	13.99
SB118M	51	5.627+/-	.623	1.0000	15.83+/-	1.75
TE119M	52	3.672+/-	.372	1.0000	16.32+/-	1.66
SB120B	51	3.404+/-	.166	1.0000	9.04+/-	.44
I 120	53	.982+/-	.452	.9017	8.80+/-	4.05
TE121M	52	2.859+/-	2.011	1.0000	7.39+/-	5.20
I 121	53	3.985+/-	1.020	.8603	18.76+/-	4.80
SB122	51	1.578+/-	.345	1.0000	7.76+/-	1.70
TE123M	52	2.499+/-	2.048	1.0000	7.37+/-	6.04
I 123	53	11.543+/-	4.095	.8113	25.74+/-	9.13
SB124	51	.643+/-	.071	1.0000	11.47+/-	1.26
I 124	53	2.527+/-	.293	1.0000	6.34+/-	.73
KE127	54	8.909+/-	.787	.6277	18.90+/-	1.67
BA128	56	2.943+/-	.434	.8637	16.45+/-	2.43
CS129	55	8.259+/-	.826	.7311	15.14+/-	1.51
BA131	56	10.576+/-	2.686	.6947	18.62+/-	4.73
LA132	57	3.337+/-	.659	.9044	9.92+/-	1.96
BA133	56	11.577+/-	3.500	.6535	23.80+/-	7.20
CE135	58	5.296+/-	3.083	.7296	11.01+/-	6.41
CE139	58	6.005+/-	1.236	.5210	14.95+/-	3.08
CE141	58	.716+/-	.156	.9726	11.83+/-	2.58
PM143	61	5.193+/-	.582	.6471	8.64+/-	.97
PM144	61	1.943+/-	.454	1.0000	4.96+/-	1.16
EU145	63	3.793+/-	.437	.8782	22.33+/-	2.57
EU146	63	9.363+/-	3.489	1.0000	38.40+/-	14.31
GD146	64	2.709+/-	2.103	.9215	45.52+/-	35.33
GD147	64	3.930+/-	.499	.8972	30.89+/-	3.92
EU148	63	2.641+/-	.198	1.0000	6.72+/-	.50
GD149	64	6.244+/-	.692	.9134	19.10+/-	2.12
TB149	65	3.873+/-	.626	.9073	41.55+/-	6.72
GD151	64	4.726+/-	1.736	.9378	11.13+/-	4.09
TB151	65	8.254+/-	4.323	.8099	26.08+/-	13.66
TB152	65	3.819+/-	2.198	.8437	9.30+/-	5.35
GD153	64	4.421+/-	2.100	.9401	15.34+/-	7.29
TB153	65	3.777+/-	1.862	.8324	7.94+/-	3.91
TB154	65	8.053+/-	1.004	1.0000	21.05+/-	2.63
DY155	66	7.960+/-	6.212	.7105	14.83+/-	11.57
TB156	65	1.068+/-	.107	1.0000	4.96+/-	.50
HQ156	67	.569+/-	.057	.7865	1.66+/-	.17
DY157	66	10.940+/-	1.094	.4326	13.59+/-	1.36
ER159	68	8.340+/-	.834	.7406	19.23+/-	1.92
ER160	68	8.471+/-	2.204	.6428	14.07+/-	3.66
TM163	69	4.834+/-	.483	.5848	7.09+/-	.71
TM165	69	14.176+/-	5.587	.3415	16.76+/-	6.60
YB166	70	5.651+/-	1.050	.5106	7.40+/-	1.37
TM167	69	13.799+/-	5.413	.1436	18.58+/-	7.29
LU167	71	7.185+/-	2.797	.6755	13.06+/-	5.08
TM168	69	1.259+/-	.071	1.0000	24.99+/-	1.41
LU169	71	8.551+/-	2.147	.5702	13.49+/-	3.39
LU170	71	17.585+/-	1.553	.7895	50.15+/-	4.43
HF170	72	6.741+/-	2.410	.6150	10.50+/-	3.76
LU171	71	10.308+/-	2.732	.7110	40.91+/-	10.84
LU172	71	2.154+/-	.299	1.0000	21.98+/-	3.05
HF172	72	14.240+/-	1.845	.4303	19.30+/-	2.50
HF173	72	20.308+/-	5.014	.4948	45.42+/-	11.22
TA173	73	10.111+/-	4.154	.5635	14.33+/-	5.89
TA176	73	15.942+/-	1.594	.3456	32.87+/-	3.29
TA176	73	8.559+/-	8.474	.3456	17.65+/-	17.47

W 176	74	22.336+/-	22.112	.4609	28.31+/-	28.02
W 177	74	41.080+/-	4.059	.3638	48.79+/-	4.82
RE179	75	15.684+/-	5.430	.4076	18.62+/-	6.45
RE181	75	14.809+/-	9.732	.2889	27.35+/-	17.97
OS181M	76	3.013+/-	1.207	1.0000	8.08+/-	3.24
RE182	75	3.485+/-	1.741	.6284	26.69+/-	13.34
OS182	76	14.240+/-	14.100	.3548	17.15+/-	16.98
OS183G	76	6.303+/-	1.341	.2856	9.15+/-	1.95
OS183M	76	8.989+/-	.327	.2845	13.00+/-	.47
IR184	77	16.164+/-	2.638	.4085	19.80+/-	3.23
IR185	77	14.012+/-	1.400	.3511	20.53+/-	2.05
PT185B	78	6.371+/-	.992	1.0000	15.97+/-	2.49
IR186	77	12.726+/-	2.595	.3061	26.75+/-	5.46
PT186	78	9.275+/-	1.748	.4543	11.54+/-	2.17
IR187	77	23.449+/-	8.949	.1968	61.73+/-	23.56
PT188	78	25.036+/-	2.410	.2193	29.71+/-	2.86
PT189	78	44.774+/-	9.954	.1456	63.84+/-	14.19
AU189	79	2.342+/-	.573	.3761	2.73+/-	.67
IR190	77	2.293+/-	.482	1.0000	4.99+/-	1.05
IR190M	77	2.793+/-	.219	1.0000	6.08+/-	.48
AU190	79	21.797+/-	.385	.2595	24.87+/-	.44
AU191	79	28.666+/-	1.477	.1977	41.93+/-	2.16
HG191	80	15.666+/-	1.894	.4327	18.99+/-	2.30
IR192	77	1.649+/-	.031	1.0000	2.70+/-	.05
HG192	80	19.354+/-	1.935	.3158	22.59+/-	2.26
HG193M	80	17.040+/-	7.288	.2189	21.54+/-	9.21
IR194M	77	.440+/-	.080	1.0000	2.74+/-	.50
AU194	79	31.364+/-	8.708	1.0000	184.01+/-	51.09
TL194M	81	12.274+/-	1.227	1.0000	39.37+/-	3.94
IR195M	77	7.530+/-	1.055	.9949	166.28+/-	23.29
PT195M	78	5.951+/-	1.136	1.0000	11.07+/-	2.11
AU195	79	71.612+/-	4.535	.9982	179.26+/-	11.35
HG195	80	65.243+/-	23.694	.0935	142.34+/-	51.69
HG195M	80	24.930+/-	14.395	1.0000	581.92+/-	336.01
AU196	79	190.420+/-	2.407	1.0000	307.44+/-	3.89
TL196	81	31.117+/-	3.665	.1661	41.31+/-	4.87
PT197	78	13.521+/-	4.239	.9904	129.10+/-	40.47
HG197M	80	28.878+/-	2.888	1.0000	116.83+/-	11.68
PB197M	82	34.303+/-	13.861	.2928	38.91+/-	15.72
AU198	79	85.232+/-	3.856	1.0000	191.37+/-	8.66
TL198	81	36.755+/-	5.071	.0902	129.38+/-	17.85
PB198	82	12.465+/-	.705	.1934	14.90+/-	.84
AU199	79	12.564+/-	2.305	.9840	60.34+/-	11.07
TL199	81	22.659+/-	4.194	.0366	92.18+/-	17.06
PB199	82	13.532+/-	2.890	.1162	18.34+/-	3.92
PB200	82	19.457+/-	3.035	.0723	36.66+/-	5.72
BI200	83	3.954+/-	.395	.2313	4.51+/-	.45
BI201	83	7.270+/-	.851	1.0000	62.92+/-	7.37
BI201M	83	8.654+/-	.865	.1429	10.70+/-	1.07
PO202	84	20.589+/-	1.453	.3814	31.96+/-	2.26
BI203	83	10.232+/-	1.618	.0484	21.85+/-	3.45
BI204	83	1.035+/-	.093	.0563	7.47+/-	.67
BI205	83	2.912+/-	2.883	.0186	23.94+/-	23.70
PO206	84	.847+/-	.839	.0401	2.68+/-	2.65
AT208	85	1.774+/-	.177	.1303	11.55+/-	1.16

XBL 778-9001

730-MEV KR-86 + AU-197

NUCLIDE A Z	EXPERIMENTAL YIELD(MB)	FRACTION INDEPENDENT	CALCULATED MASS YIELD(MB)
EXPERIMENT 57AU 730-MEV KR-86 + AU-197			
SC 44M 21	.837+/-	.286	1.0000 2.85+/- .97
SC 48 21	.975+/-	.066	1.0000 37.28+/- 2.52
MN 52 25	.481+/-	.101	.9896 1.20+/- .25
MN 56 25	2.992+/-	.576	.9071 19.08+/- 3.67
FE 59 26	2.184+/-	.523	.8865 17.44+/- 4.18
CU 60 29	14.376+/-	9.545	.8252 49.67+/- 32.98
GE-66 32	8.475+/-	2.664	.8954 78.90+/- 24.80
CU 67 29	13.030+/-	1.303	.8968 124.42+/- 12.44
AS 69 33	6.625+/-	1.140	.8783 46.57+/- 8.01
ZN 71M 30	3.673+/-	.739	1.0000 116.16+/- 23.37
ZN 72 30	2.319+/-	1.131	.9579 181.29+/- 88.46
GA 72 31	12.448+/-	.297	1.0000 119.61+/- 2.86
GA 74 31	4.599+/-	4.435	.9476 201.64+/- 194.47
AS 74 33	8.454+/-	2.480	1.0000 23.10+/- 6.77
BR 74 35	9.500+/-	3.607	.9491 79.39+/- 30.15
SE 75 34	75.854+/-	13.725	.9518 184.52+/- 33.39
AS 76 33	21.320+/-	2.132	1.0000 108.51+/- 10.85
KR 76 36	8.511+/-	.848	.9067 99.49+/- 9.91
GE 77 32	3.068+/-	.766	.9553 203.78+/- 50.88
BR 77 35	5.816+/-	.073	.9534 15.19+/- .19
KR 79 36	6.105+/-	4.944	.9072 17.11+/- 13.86
SR 79 38	4.790+/-	1.428	.9582 381.90+/- 113.84
BR 82 35	43.777+/-	.966	1.0000 346.46+/- 7.64
RB 82M 37	8.339+/-	.351	1.0000 23.50+/- .99
RB 83 37	14.872+/-	.435	.9972 37.34+/- 1.09
RB 84 37	27.872+/-	5.776	1.0000 72.90+/- 15.11
RB 84M 37	32.927+/-	8.041	1.0000 86.12+/- 21.03
Y 85M 39	8.335+/-	2.654	1.0000 49.96+/- 15.91
Y 86 39	4.493+/-	.670	1.0000 17.40+/- 2.60
Y 86M 39	4.949+/-	.479	1.0000 19.17+/- 1.86
ZR 86 40	7.232+/-	.563	.9170 107.62+/- 8.37
Y 87 39	2.801+/-	.190	.9684 7.89+/- .54
Y 88 39	20.279+/-	1.766	.4279 22.02+/- 1.92
ZR 88 40	3.822+/-	2.507	.9220 17.26+/- 11.32
NB 88 41	.753+/-	.745	1.0000 19.34+/- 19.15
ZR 89 40	10.960+/-	1.096	.9737 35.97+/- 3.60
Y 90M 39	22.967+/-	1.024	1.0000 69.68+/- 3.11
NB 90 41	2.794+/-	.041	.9962 18.13+/- .27
Y 91M 39	20.506+/-	1.997	1.0000 85.23+/- 8.30
Y 92 39	29.135+/-	2.745	.9921 191.27+/- 18.02
NB 92M 41	.518+/-	.120	1.0000 1.56+/- .36
MO 93M 42	4.124+/-	.062	1.0000 21.73+/- .32
Y 94 39	6.849+/-	.685	.9369 168.96+/- 16.90
TC 94 43	1.669+/-	.065	.9856 22.05+/- .86
TC 94M 43	1.016+/-	1.005	1.0000 13.62+/- 13.47
ZR 95 40	18.211+/-	.776	.9375 143.69+/- 6.13
NB 95 41	18.494+/-	1.603	1.0000 54.12+/- 4.69
TC 95 43	3.674+/-	.300	.9881 25.79+/- 2.11
TC 95M 43	8.181+/-	2.511	1.0000 58.12+/- 17.84
NB 96 41	14.507+/-	.670	1.0000 56.79+/- 2.62
TC 96 43	5.551+/-	.146	1.0000 24.30+/- .64
RU 97 44	4.413+/-	.371	.9751 43.36+/- 3.65
NB 98 41	12.021+/-	2.428	.8985 118.75+/- 23.98

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MD 99	42	19.987+/-	.534	.8444	78.10+/-	2.09
RH 99M	45	1.032+/-	.257	.9800	15.21+/-	3.79
RM100	45	18.968+/-	5.264	1.0000	147.55+/-	40.95
MD101	42	14.400+/-	1.440	.9129	193.88+/-	19.39
RM101M	45	6.127+/-	1.274	1.0000	28.67+/-	6.06
TC102	43	7.441+/-	.744	1.0000	41.80+/-	4.18
RU103	44	29.322+/-	2.220	.7407	67.59+/-	5.12
RU105	44	14.149+/-	1.022	.9174	90.91+/-	6.57
RM105	45	21.520+/-	3.311	.9864	58.45+/-	8.99
RM106M	45	14.583+/-	4.429	1.0000	51.21+/-	15.55
AG106M	47	3.733+/-	.110	1.0000	18.74+/-	.55
RM107	45	6.880+/-	1.635	.8661	31.02+/-	7.37
RM108B	45	3.533+/-	.749	1.0000	31.68+/-	6.71
IN110M	49	1.730+/-	.118	1.0000	16.32+/-	1.11
CD111M	48	8.437+/-	.844	1.0000	21.77+/-	2.18
IN111	49	5.392+/-	.542	.9634	28.10+/-	2.82
CU115	48	3.788+/-	1.544	.9491	21.27+/-	8.67
SB115	51	2.622+/-	.262	.9248	25.33+/-	2.53
IN116M	49	4.205+/-	1.438	1.0000	13.45+/-	4.60
SB116M	51	6.000+/-	2.075	1.0000	35.09+/-	12.14
TE116	52	1.911+/-	.615	.9416	63.77+/-	20.51
IN117	49	5.645+/-	.565	1.0000	25.52+/-	2.55
SB118M	51	3.954+/-	.083	1.0000	11.38+/-	.24
TE119M	52	3.206+/-	.528	1.0000	15.37+/-	2.53
I 119	53	1.284+/-	.295	.9499	30.10+/-	6.91
SB120B	51	3.333+/-	.385	1.0000	8.62+/-	1.00
I 120	53	1.201+/-	.260	.9799	13.67+/-	2.95
SB122	51	2.208+/-	.361	1.0000	9.35+/-	1.53
I 124	53	3.121+/-	.409	1.0000	7.98+/-	1.05
XE127	54	11.114+/-	.781	.9846	27.45+/-	1.93
BA128	56	2.021+/-	.224	.9184	18.13+/-	2.01
CS129	55	8.986+/-	.899	.9680	22.56+/-	2.26
I 130	53	.523+/-	.122	1.0000	12.56+/-	2.94
BA131M	56	3.609+/-	1.027	1.0000	10.18+/-	2.90
LA132	57	4.202+/-	.420	.9930	19.12+/-	1.91
CE135	58	4.623+/-	.075	.9282	16.66+/-	.27
LA140	57	.607+/-	.126	1.0000	11.31+/-	2.34
EU146	63	3.003+/-	.175	1.0000	30.40+/-	1.77
PM148	61	1.980+/-	.160	1.0000	9.13+/-	.74
PM148M	61	2.251+/-	.143	1.0000	10.38+/-	.66
EU148	63	2.773+/-	1.926	1.0000	10.38+/-	7.21
GD149	64	4.942+/-	.270	.9954	38.43+/-	2.10
TB151	65	2.530+/-	.670	.9626	27.38+/-	7.24
TB152	65	3.445+/-	.230	.9907	21.13+/-	1.41
TB153	65	6.823+/-	.701	.9915	26.80+/-	2.75
TB155	65	8.763+/-	.253	.9920	22.15+/-	.64
TB156	65	1.484+/-	.069	1.0000	3.80+/-	.18
HO156	67	2.936+/-	.621	.9243	33.99+/-	7.19
DY157	66	6.232+/-	1.447	.8442	14.32+/-	3.32
HO159	67	9.000+/-	2.427	1.0000	27.52+/-	7.42
ER159	68	6.665+/-	.211	.8898	56.18+/-	1.78
ER160	68	7.557+/-	.739	.8431	34.57+/-	3.38
TM163	69	5.752+/-	.989	.9013	23.28+/-	4.00
TM165	69	13.721+/-	.537	.7890	28.42+/-	1.11
VB166	70	3.208+/-	.113	.7912	9.68+/-	.34
TM167	69	16.369+/-	9.394	.6814	31.24+/-	17.93
VB167	70	10.502+/-	.654	1.0000	30.28+/-	1.88
VB169	70	19.518+/-	3.569	.9962	50.23+/-	9.19
LU169	71	15.309+/-	1.981	.9733	49.61+/-	6.42
LU170	71	19.453+/-	3.846	.9945	51.85+/-	10.25
MF170	72	7.031+/-	1.395	.8595	38.50+/-	7.64
LU171	71	19.409+/-	3.377	.9926	48.30+/-	8.40

MF171	72	1.013+/-	.612	.8019	3.29+/-	1.99
LU172	71	2.999+/-	.228	1.0000	8.17+/-	.62
HF173	72	24.808+/-	2.405	.9785	62.11+/-	6.02
TA173	73	13.259+/-	1.832	.9309	63.78+/-	8.81
TA174	73	15.370+/-	1.537	.9320	50.06+/-	5.01
TA175	73	17.898+/-	7.219	.9131	44.88+/-	18.10
TA176	73	19.156+/-	4.440	.9634	46.29+/-	10.73
HF177M	72	12.290+/-	1.228	1.0000	76.41+/-	7.63
TA177	73	27.419+/-	3.306	.9363	68.36+/-	8.24
W 177	74	17.438+/-	14.243	.8850	47.85+/-	39.08
RE177	75	7.354+/-	.735	.9082	65.54+/-	6.55
RE178	75	14.513+/-	1.318	.8744	70.74+/-	6.42
RE179	75	17.012+/-	4.453	.8512	53.30+/-	13.95
RE181	75	14.131+/-	5.980	.9527	33.92+/-	14.35
OS182	76	17.618+/-	1.486	.8844	50.38+/-	4.25
IR182	77	8.743+/-	2.821	.9961	94.76+/-	30.57
OS183	76	17.930+/-	1.793	.9375	44.43+/-	4.44
CS183M	76	8.885+/-	.579	.9375	22.02+/-	1.44
RE184	75	12.785+/-	5.665	1.0000	56.31+/-	24.95
IR184	77	13.998+/-	.694	.8783	47.86+/-	2.37
OS185	76	44.999+/-	3.113	.9875	123.23+/-	8.52
IR185	77	16.477+/-	3.728	.9561	45.95+/-	10.40
PT185B	78	16.059+/-	3.345	1.0000	133.91+/-	27.89
IR186	77	16.792+/-	1.777	.9656	41.18+/-	4.36
IR186M	77	14.793+/-	4.943	1.0000	37.57+/-	12.55
PT186	78	8.172+/-	.578	.9134	36.78+/-	2.60
AU186	79	5.782+/-	1.516	.9358	140.63+/-	36.87
IR187	77	45.882+/-	6.122	.9504	112.10+/-	14.96
IR188	77	17.265+/-	5.415	1.0000	52.21+/-	16.38
IR188	77	12.491+/-	2.730	1.0000	37.77+/-	8.25
PT188	78	23.032+/-	2.955	.7846	48.82+/-	6.26
AU188	79	9.848+/-	.565	.8766	54.65+/-	3.25
PT189	78	47.216+/-	5.550	.8524	100.89+/-	11.86
IR190	77	2.646+/-	.059	1.0000	6.18+/-	.14
IR190M	77	10.938+/-	1.781	1.0000	25.55+/-	4.16
AU190	79	29.904+/-	7.980	.8888	80.34+/-	21.44
HG190	80	4.166+/-	.417	.8878	33.99+/-	3.40
PT191	78	60.056+/-	11.401	.9239	187.89+/-	35.67
AU191	79	23.353+/-	5.025	.9276	55.68+/-	11.98
HG191	80	15.874+/-	1.602	.9080	76.44+/-	7.71
IR192	77	2.786+/-	.618	1.0000	72.36+/-	16.09
IR192	77	2.780+/-	.618	1.0000	4.46+/-	.99
HG192	80	16.530+/-	1.653	.8705	51.18+/-	5.12
HG192	80	11.401+/-	2.537	.8705	35.30+/-	7.85
TL192	81	.392+/-	.388	.9090	4.82+/-	4.77
HG193M	80	15.825+/-	3.524	.8866	38.90+/-	8.66
AU194	79	37.172+/-	1.677	1.0000	230.15+/-	10.39
TL194	81	9.438+/-	.944	.8960	37.22+/-	3.72
TL194M	81	6.148+/-	6.087	1.0000	27.06+/-	26.79
IR195M	77	8.893+/-	1.642	.9965	187.48+/-	34.61
PT195M	78	60.271+/-	3.914	1.0000	110.64+/-	7.18
HG195M	80	24.020+/-	2.402	1.0000	63.50+/-	6.35
PB195M	82	1.706+/-	1.689	.9039	15.68+/-	15.52
AU196	79	211.530+/-	6.604	1.0000	342.71+/-	10.70
TL196	81	29.687+/-	3.824	.9043	70.09+/-	9.03
TL196M	81	27.955+/-	4.335	1.0000	72.99+/-	11.32
HG197M	80	32.860+/-	3.286	1.0000	132.54+/-	13.25
TL197	81	1.657+/-	.292	.8710	3.64+/-	.64
PB197M	82	5.311+/-	3.783	.8025	15.99+/-	11.39
AU198	79	116.480+/-	4.800	1.0000	264.78+/-	10.91
AU198M	79	6.314+/-	1.615	1.0000	350.97+/-	89.76
TL198	81	42.461+/-	4.388	.9296	111.54+/-	11.53

TL198M	81	22.341+/-	3.382	1.0000	63.13+/-	9.56
PB198	82	10.300+/-	.838	.8380	24.64+/-	2.00
B1198	83	5.729+/-	.573	.8829	39.67+/-	3.97
AU199	79	16.922+/-	5.947	.9958	85.52+/-	30.06
HG199M	80	14.097+/-	5.633	1.0000	21.36+/-	8.53
TL199	81	21.776+/-	2.416	.8361	67.05+/-	7.44
PB199	82	18.550+/-	1.855	.8477	39.71+/-	3.97
TL200	81	30.947+/-	6.858	.9753	168.40+/-	37.32
PB200	82	53.507+/-	9.560	.8274	114.93+/-	20.53
B1200	83	24.999+/-	9.645	.8613	70.71+/-	27.28
TL201	81	6.008+/-	.864	.9090	53.64+/-	7.71
PB201	82	8.247+/-	.825	.8935	22.85+/-	2.29
TL202	81	4.52+/-	.054	1.0000	9.09+/-	1.08
PB202M	82	5.993+/-	1.138	1.0000	25.81+/-	4.90
B1202	83	4.653+/-	.810	.8821	10.30+/-	1.19
PB203	82	4.708+/-	.280	.9461	30.96+/-	1.84
B1203	83	64.444+/-	6.729	.7744	137.10+/-	14.32
P0203	84	31.184+/-	19.819	.8212	75.59+/-	48.04
PB204M	82	4.383+/-	1.619	1.0000	57.12+/-	21.09
B1204	83	1.178+/-	.081	.9260	3.81+/-	.26
P0205	84	10.875+/-	3.314	.8342	23.22+/-	7.08

EXPERIMENT AU64AU 730-MEV KR-86 + AU-197

I 120	53	.903+/-	.090	.9097	9.54+/-	.95
I 121	53	1.398+/-	.018	.8924	7.92+/-	.10
I 121	53	2.222+/-	.775	.8782	12.39+/-	4.32
I 124	53	3.011+/-	.439	1.0000	7.70+/-	1.12
I 126	53	1.924+/-	.101	1.0000	5.69+/-	.30
I 130	53	.210+/-	.021	1.0000	5.04+/-	.50
AU190	79	10.120+/-	.222	.6846	20.94+/-	.46
AU191	79	13.500+/-	.204	.7191	24.95+/-	.38
AU192	79	14.000+/-	.306	.8538	30.37+/-	.66
AU193	79	16.460+/-	1.040	.8780	42.17+/-	2.66
AU194	79	33.860+/-	3.386	1.0000	131.87+/-	13.19
AU194	79	33.860+/-	3.386	1.0000	209.65+/-	20.97
AU195	79	34.000+/-	1.000	1.0000	205.43+/-	6.04
AU195	79	34.000+/-	1.000	1.0000	87.11+/-	2.56
AU196	79	136.100+/-	11.500	1.0000	220.51+/-	18.63
AU196M	79	17.880+/-	1.605	1.0000	194.77+/-	17.48
AU198	79	86.310+/-	2.912	1.0000	196.20+/-	6.62
AU198M	79	5.533+/-	.374	1.0000	307.57+/-	20.76
AU199	79	8.499+/-	.635	.9853	42.50+/-	3.18
AU200	79	.473+/-	.171	1.0000	244.73+/-	88.65
AU200	79	.473+/-	.171	1.0000	8.11+/-	2.94
AU200M	79	.047+/-	.005	1.0000	24.56+/-	2.62
AU200M	79	.047+/-	.005	1.0000	.81+/-	.09
AT206	85	2.070+/-	.919	1.0000	5.64+/-	2.51
AT207	85	1.463+/-	.478	.6132	2.25+/-	.74
AT208	85	1.774+/-	.193	.5274	2.51+/-	.27
AT209	85	1.384+/-	1.370	.4763	2.20+/-	2.17

EXPERIMENT TL64AU 730-MEV KR-86 + AU-197

TL198M	81	4.847+/-	.335	1.0000	21.34+/-	1.48
TL195	81	8.122+/-	.151	.7540	19.26+/-	.36
TL195	81	6.031+/-	1.047	.7580	14.38+/-	2.50
TL196	81	4.080+/-	.296	.6821	7.27+/-	.53
TL196M	81	26.206+/-	2.621	1.0000	68.42+/-	6.84
TL197	81	6.605+/-	1.106	.6012	13.04+/-	1.68
TL198	81	20.440+/-	.989	.6789	39.21+/-	1.90
TL198	81	13.480+/-	2.020	.6789	25.86+/-	3.88

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TL198M	81	21.130+/-	1.658	1.0000	59.71+/-	4.69
TL198M	81	13.602+/-	3.001	1.0000	38.44+/-	8.48
TL199	81	23.930+/-	3.083	.4796	42.27+/-	5.45
TL200	81	10.470+/-	.234	.8490	49.60+/-	1.11
TL201	81	4.400+/-	.851	.5959	25.75+/-	4.98
TL202	81	.745+/-	.013	1.0000	14.97+/-	.26

EXPERIMENT HG64AU 730-MEV KR-86 + AU-197

HG191	80	9.525+/-	3.553	.8182	41.33+/-	15.42
HG192	80	12.960+/-	12.830	.7749	35.72+/-	35.36
HG193	80	9.000+/-	4.500	.7132	17.79+/-	8.90
HG193M	80	15.241+/-	2.706	.7170	30.29+/-	5.38
HG195	80	17.010+/-	.905	.6214	27.95+/-	1.49
HG195	80	1.389+/-	.391	.6214	2.28+/-	.64
HG195M	80	23.560+/-	1.977	1.0000	62.29+/-	5.23
HG197M	80	36.610+/-	.675	1.0000	168.40+/-	3.11
HG197M	80	36.610+/-	.675	1.0000	147.66+/-	2.72
HG199M	80	7.232+/-	7.160	1.0000	105.58+/-	104.53
HG199M	80	7.232+/-	7.160	1.0000	10.96+/-	10.85

EXPERIMENT LA64AU 730-MEV KR-86 + AU-197

SC 43	21	.389+/-	.120	.4545	.48+/-	.15
SC 46	21	.908+/-	.208	1.0000	7.67+/-	1.76
SC 47	21	.479+/-	.048	1.0000	7.98+/-	.80
SC 48	21	.961+/-	.103	1.0000	36.77+/-	3.94
SR 83	38	.495+/-	.007	.8344	1.89+/-	.03
SR 85	38	4.001+/-	.173	.9392	9.91+/-	.43
Y 85M	39	.278+/-	.028	1.0000	1.67+/-	.17
Y 86	39	3.053+/-	.080	1.0000	11.82+/-	.31
Y 87	39	.364+/-	.160	.8835	.93+/-	.41
Y 87M	39	8.624+/-	.862	.8823	22.13+/-	2.21
Y 87	39	1.562+/-	.156	.8823	4.01+/-	.40
Y 88	39	13.640+/-	.202	.4279	14.81+/-	.22
ZR 88	40	1.114+/-	.040	.8549	4.66+/-	.17
ZR 89	40	2.644+/-	.264	.9026	8.04+/-	.80
Y 90M	39	14.220+/-	.146	1.0000	43.14+/-	.44
SR 91	38	3.256+/-	.225	.9233	56.32+/-	3.88
Y 91M	39	19.370+/-	19.180	1.0000	80.51+/-	79.72
Y 91M	39	12.430+/-	11.140	1.0000	51.66+/-	46.30
SR 92	38	1.347+/-	1.334	.9465	56.04+/-	55.50
Y 92	39	11.670+/-	.715	.9645	74.49+/-	4.56
Y 94	39	4.116+/-	.412	.9337	101.19+/-	10.12
ZR 95	40	4.800+/-	.068	.8952	36.17+/-	.51
CS127	55	.613+/-	.331	.8380	2.21+/-	1.19
CS127	55	4.728+/-	4.680	.8163	16.56+/-	16.40
BA128	56	.709+/-	.060	.8969	6.21+/-	.53
CS129	55	1.592+/-	.664	.8756	3.62+/-	1.51
BA129	56	1.975+/-	.164	.8568	9.40+/-	.78
BA131	56	4.426+/-	.143	.8355	10.43+/-	.34
LA131	57	1.968+/-	.100	.8809	13.11+/-	.67
LA132	57	2.760+/-	.263	.9673	12.24+/-	1.17
LA132	57	1.324+/-	.088	.9673	5.87+/-	.39
CE132	58	.832+/-	.188	.9290	17.53+/-	3.97
BA133	56	2.854+/-	1.515	.8600	6.41+/-	3.41
CE133	58	.482+/-	.017	.8977	4.68+/-	.17
CE134	58	.230+/-	.004	.8798	1.22+/-	.02
CS135M	55	.328+/-	.235	1.0000	6.92+/-	4.96
CE135	58	4.102+/-	.372	.8380	13.35+/-	1.21
CE137M	58	1.919+/-	.344	1.0000	4.87+/-	.87
PR138M	59	2.017+/-	.039	1.0000	6.81+/-	.13

CE139	58	7.615+/-	.762	.8163	18.83+/-	1.88
ND139M	60	1.955+/-	.115	1.0000	12.78+/-	.75
LA140	57	.100+/-	.068	1.0000	1.87+/-	1.27
PM143	61	4.075+/-	.705	.7947	11.49+/-	1.99
PM144	61	2.237+/-	.020	1.0000	6.19+/-	.06
PR145	59	.524+/-	.078	.9200	7.96+/-	1.19
EU146	63	3.633+/-	.180	1.0000	36.77+/-	1.82
EU147	63	5.410+/-	.382	.9985	30.84+/-	2.18
EU148	63	3.498+/-	.101	1.0000	13.09+/-	.38
EU149	63	8.770+/-	.666	.9988	24.98+/-	1.90
GO149	64	6.325+/-	.581	.9792	48.37+/-	4.45
TB150A	65	.375+/-	.037	.9352	8.31+/-	.83
GO151	64	3.363+/-	.660	.9880	10.89+/-	2.14
TB152	65	5.190+/-	.614	.9606	30.86+/-	3.65
DY152	66	1.619+/-	.162	.9450	59.90+/-	5.99
GO153	64	6.550+/-	.815	.9903	16.28+/-	2.03
TB153	65	6.869+/-	1.593	.9622	26.19+/-	6.07
TB154	65	.581+/-	.061	1.0000	1.71+/-	.18
TB154M	65	.525+/-	.074	1.0000	1.55+/-	.22
TB155	65	8.815+/-	1.565	.9624	21.62+/-	3.84
DY155	66	6.058+/-	.589	.9030	27.56+/-	2.68
TB156	65	1.781+/-	.133	1.0000	4.56+/-	.34
HO156	67	.304+/-	.039	.9072	3.45+/-	.44
DY157	66	8.595+/-	.859	.7219	16.89+/-	1.69
ER158	68	3.341+/-	.620	.9234	59.29+/-	11.01
HO159	67	22.030+/-	.588	1.0000	67.37+/-	1.80
ER159	68	4.574+/-	4.528	.8897	38.55+/-	38.17
ER160	68	8.390+/-	1.932	.8430	38.39+/-	8.84
HO161	67	5.266+/-	5.214	1.0000	13.34+/-	13.21
ER161	68	7.675+/-	.701	.8368	23.21+/-	2.12
TM161	69	3.102+/-	.310	.9106	39.58+/-	3.96
HO162M	67	1.713+/-	.171	1.0000	4.75+/-	.49
TM163	69	5.219+/-	.625	.8334	19.53+/-	2.34
TM163	69	7.961+/-	7.882	.8192	29.28+/-	28.99
TM165	69	14.130+/-	1.162	.6852	25.42+/-	2.09
TM166	69	.887+/-	.433	1.0000	2.23+/-	1.09
YB166	70	3.351+/-	.138	.7911	10.12+/-	.42
TM167	69	16.160+/-	2.742	.4893	22.14+/-	3.76
LU167	71	2.180+/-	.482	.8789	15.46+/-	3.42
TM168	69	1.075+/-	.070	1.0000	3.90+/-	.25
YB169	70	14.231+/-	2.884	.9814	36.08+/-	7.31
LU169	71	9.299+/-	.630	.9008	27.89+/-	1.89
LU170	71	7.840+/-	.585	.9736	20.46+/-	1.53
HF170	72	6.742+/-	.726	.8595	36.92+/-	3.97
ER171	68	.198+/-	.038	.9710	46.31+/-	8.78
LU171	71	6.342+/-	.488	.9648	15.34+/-	1.18
HF171	72	5.076+/-	3.481	.8018	16.46+/-	11.29
LU172	71	3.541+/-	.284	1.0000	9.65+/-	.77
HF172	72	14.305+/-	4.656	.8278	35.34+/-	11.50
HF177M	72	2.567+/-	.257	1.0000	15.96+/-	1.60
HF179M	72	2.804+/-	.453	1.0000	66.97+/-	10.82
PB196	82	13.310+/-	1.331	.8530	65.04+/-	6.50
PB197M	82	12.140+/-	2.214	.7981	36.35+/-	6.63
PB198	82	16.680+/-	16.521	.7324	34.88+/-	34.55
PB198	82	14.731+/-	2.662	.7324	30.80+/-	5.57
PB199	82	13.780+/-	.407	.6683	23.26+/-	.69
PB200	82	20.710+/-	2.071	.6115	32.88+/-	3.29
PB201	82	13.490+/-	3.013	.6650	27.83+/-	6.21
PB202M	82	4.122+/-	.641	1.0000	17.75+/-	2.76
PB203	82	6.265+/-	.812	.7830	34.09+/-	4.42

620-MEV KR-86 + AU-197

NUCLIDE A Z	EXPERIMENTAL YIELD(MB)	FRACTION INDEPENDENT	CALCULATED MASS YIELD(MB)
EXPERIMENT 61AU	620-MEV KR-86 + AU-197		
SC 46 21	.455+/- .417	1.0000	2.10+/- 1.93
SC 48 21	.292+/- .168	1.0000	4.47+/- 2.57
FE 52 26	.526+/- .126	.8765	3.60+/- .86
CO 58 27	.566+/- .249	1.0000	1.43+/- .63
FE 59 26	1.225+/- .166	.8475	5.87+/- .79
CU 67 29	5.127+/- .513	.8705	32.30+/- 3.23
GE 69 32	1.117+/- .330	.7602	2.82+/- .83
ZN 71M 30	2.307+/- .231	1.0000	46.95+/- 4.70
ZN 72 30	1.001+/- .496	.9491	47.23+/- 23.41
GA 72 31	4.729+/- 1.383	1.0000	33.64+/- 9.83
AS 74 33	3.272+/- .327	1.0000	8.44+/- .84
SE 75 34	1.869+/- .103	.6838	3.42+/- .19
AS 76 33	11.913+/- 6.254	1.0000	51.00+/- 26.77
BR 77 35	1.323+/- .245	.7268	2.83+/- .53
AS 78 33	20.035+/- 1.585	.9084	243.32+/- 19.25
BR 82 35	26.511+/- .504	1.0000	182.18+/- 3.47
RB 82M 37	2.588+/- 1.322	1.0000	7.67+/- 3.92
SR 82 38	25.360+/- 5.344	.8850	195.95+/- 41.29
BR 83 35	17.680+/- 17.510	.9074	209.84+/- 207.82
RB 83 37	8.878+/- 1.115	.8225	18.61+/- 2.34
BR 84 37	15.768+/- 1.576	1.0000	40.43+/- 4.04
KR 85M 36	89.489+/- .112	.8879	731.43+/- .91
Y 85M 39	6.940+/- 1.220	1.0000	45.51+/- 8.00
SR 85 38	7.058+/- .189	.7146	13.63+/- .37
RB 86 37	59.026+/- 3.104	1.0000	246.55+/- 12.97
Y 86 39	29.458+/- 12.906	1.0000	120.46+/- 52.78
Y 87 39	6.103+/- .610	.7348	13.39+/- 1.34
Y 87 39	3.133+/- .558	1.0000	9.36+/- 1.67
Y 87M 39	14.817+/- .393	.7291	32.26+/- .85
Y 88 39	11.331+/- .497	.4379	12.67+/- .56
ZR 88 40	1.631+/- .073	.8370	6.98+/- .31
ZR 89 40	4.342+/- .434	.7758	11.60+/- 1.16
Y 90M 39	13.593+/- .338	1.0000	40.82+/- 1.01
NB 90 41	.305+/- .105	.8733	1.78+/- .61
NB 92M 41	.297+/- .112	1.0000	.89+/- .34
MC 93M 42	9.749+/- 2.563	1.0000	50.58+/- 13.30
TC 94 43	1.136+/- .013	.9066	13.24+/- .15
NB 96 41	8.229+/- .791	1.0000	33.56+/- 3.22
TC 96 43	3.743+/- .089	1.0000	15.65+/- .37
RU 97 44	1.506+/- .519	.8896	12.37+/- 4.27
MC 99 42	12.818+/- 2.694	.8340	53.72+/- 11.29
RH 99 45	6.378+/- 2.952	1.0000	83.84+/- 38.81
RH100 45	1.411+/- .132	1.0000	9.73+/- .91
RH101 45	1.586+/- .529	.8517	5.73+/- 1.91
RH101M 45	2.289+/- .377	1.0000	9.71+/- 1.66
RU103 44	15.630+/- 1.563	.7634	40.22+/- 4.02
RU105 44	5.591+/- .304	.8828	41.72+/- 2.29
RH105 45	10.610+/- 1.061	.7412	23.12+/- 2.31
RU106 44	4.161+/- 1.603	.9192	65.78+/- 25.34
RH106M 45	5.413+/- 1.152	1.0000	21.57+/- 4.59
AG106M 47	2.446+/- .279	1.0000	10.50+/- 1.20
AG110M 47	3.763+/- .318	1.0000	10.99+/- .93
IN110M 49	1.046+/- 1.035	1.0000	7.47+/- 7.39

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IN111	49	1.392+/-	.181	.8159	4.94+/-	.64
SN113	50	2.724+/-	.118	.8450	12.67+/-	.55
IN114M	49	2.690+/-	2.143	1.0000	6.81+/-	5.43
CD115	48	1.274+/-	.300	.8811	9.23+/-	2.17
SB118M	51	1.568+/-	.294	1.0000	4.07+/-	.76
TE119M	52	1.196+/-	.502	1.0000	4.37+/-	1.84
SB120B	51	1.929+/-	.263	1.0000	5.56+/-	.76
TE121M	52	1.909+/-	.741	1.0000	4.80+/-	1.86
I 121	53	1.597+/-	.220	.8176	5.82+/-	.80
SB122	51	1.014+/-	.101	1.0000	6.11+/-	.61
TE123M	52	1.817+/-	.776	1.0000	5.91+/-	2.52
I 124	53	1.846+/-	.290	1.0000	4.66+/-	.73
KE127	54	5.425+/-	.658	.5344	7.63+/-	.93
BA131	56	4.557+/-	.218	.6090	6.99+/-	.33
LA132	57	.915+/-	.092	.7502	2.20+/-	.22
BA133	56	3.181+/-	.283	.3937	4.00+/-	.36
CE133	58	.365+/-	.361	.8511	1.82+/-	1.80
CE135	58	2.818+/-	.419	.7079	5.69+/-	.84
PR138M	59	1.868+/-	.351	1.0000	4.92+/-	.93
CE139	58	4.113+/-	.232	.2811	5.21+/-	.29
PM143	61	2.389+/-	.227	.6641	4.19+/-	.40
PM144	61	1.767+/-	.227	1.0000	4.44+/-	.57
EU145	63	1.054+/-	.209	.8803	7.51+/-	1.49
EU146	63	1.072+/-	.179	1.0000	5.11+/-	.85
GD147	64	1.780+/-	1.762	.9018	18.15+/-	17.97
PM148	61	.898+/-	.277	1.0000	8.95+/-	2.76
EU148	63	1.602+/-	.376	1.0000	4.25+/-	1.00
GD149	64	1.884+/-	.048	.8162	6.00+/-	.15
TB149	65	.784+/-	.776	.9175	11.85+/-	11.73
TB152	65	.731+/-	.091	.7648	1.05+/-	.23
GO153	64	3.094+/-	.776	.7170	6.87+/-	1.72
TB153	65	2.110+/-	.098	.6925	3.89+/-	.18
DY155	66	2.517+/-	.252	.7188	5.29+/-	.53
TB156	65	1.342+/-	.131	1.0000	4.80+/-	.47
DY157	66	6.208+/-	.621	.5027	8.05+/-	.81
ER160	68	2.589+/-	.479	.7207	5.49+/-	1.02
TM165	69	8.450+/-	2.168	.4475	10.36+/-	2.66
VB166	70	2.110+/-	.244	.6250	3.36+/-	.39
TM167	69	14.070+/-	.779	.2195	16.22+/-	.90
TM168	69	1.505+/-	1.058	1.0000	13.87+/-	9.75
VB169	70	10.014+/-	1.430	.5264	22.04+/-	3.15
LU169	71	9.290+/-	1.878	.5784	13.47+/-	2.72
LU170	71	9.219+/-	.942	.5443	13.68+/-	1.40
NF170	72	10.372+/-	1.114	.7260	22.48+/-	2.41
LU171	71	14.875+/-	3.480	.4450	22.97+/-	5.37
LU172	71	3.515+/-	.262	1.0000	18.19+/-	1.35
NF172	72	22.810+/-	5.743	.5194	30.32+/-	7.63
LU173	71	17.115+/-	1.770	.2608	40.36+/-	4.18
NF173	72	25.297+/-	6.836	.4070	30.93+/-	8.36
TA174	73	7.718+/-	.772	.5743	11.11+/-	1.11
NF175	72	15.316+/-	.768	.2388	24.33+/-	1.22
TA175	73	25.379+/-	2.362	.4550	31.32+/-	2.91
TA176	73	15.000+/-	10.000	.3348	17.26+/-	11.51
TA177	73	19.024+/-	.757	.2338	22.70+/-	.90
W 177	74	11.339+/-	3.741	.5171	14.97+/-	4.94
RE181	75	10.228+/-	3.363	.3414	11.89+/-	3.91
RE182	75	11.631+/-	2.159	.3681	21.54+/-	4.00
OS182	76	10.628+/-	1.226	.5216	14.12+/-	1.63
RE183	75	22.213+/-	.775	.2136	41.28+/-	1.44
OS183	76	10.980+/-	.393	.4000	13.01+/-	.47
OS183M	76	4.042+/-	.111	.3994	4.78+/-	.13
IR184	77	8.386+/-	.553	.5812	12.22+/-	.81

IR185	77	8.909+/-	1.979	.4642	11.11+/-	2.47
IR186	77	10.846+/-	1.583	.3460	12.66+/-	1.85
PT186	78	2.703+/-	.567	.6379	4.44+/-	.93
IR187	77	18.615+/-	8.748	.2328	21.50+/-	10.10
IR188	77	5.561+/-	.687	1.0000	47.49+/-	5.86
PT188	78	16.286+/-	2.189	.4030	19.30+/-	2.59
IR189	77	34.193+/-	3.181	.1167	68.75+/-	6.40
PT189	78	35.184+/-	1.339	.2848	39.95+/-	1.52
IR190	77	2.784+/-	.134	1.0000	6.50+/-	.31
IR190M	77	6.717+/-	1.017	1.0000	15.69+/-	2.37
OS191	76	1.987+/-	1.273	.9755	7.50+/-	4.81
PT191	78	26.294+/-	4.563	.1192	36.87+/-	6.40
IR192	77	2.651+/-	.458	1.0000	4.25+/-	.73
MG192	80	8.947+/-	.895	.5280	11.99+/-	1.26
MG193M	80	9.390+/-	.426	.4062	11.15+/-	.51
IR194M	77	.780+/-	.067	1.0000	4.60+/-	.39
AU194	79	27.419+/-	2.879	1.0000	169.77+/-	17.82
IR195M	77	3.829+/-	.383	.9946	80.58+/-	8.06
PT195M	78	13.197+/-	1.622	1.0000	24.23+/-	2.98
AU195	79	81.688+/-	6.171	.9865	206.45+/-	15.60
MG195M	80	17.251+/-	5.415	1.0000	107.42+/-	33.72
AU196	79	162.300+/-	16.230	1.0000	262.95+/-	26.30
TL196	81	19.481+/-	.623	.3470	22.39+/-	.72
MG197M	80	25.050+/-	2.505	1.0000	101.04+/-	10.10
AU198	79	85.166+/-	7.387	1.0000	193.60+/-	16.79
TL198	81	61.133+/-	15.520	.1476	74.22+/-	18.84
TL198M	81	17.542+/-	2.140	1.0000	144.33+/-	17.60
PB198	82	8.992+/-	.802	.4094	10.69+/-	.95
AU199	79	12.839+/-	.971	.4988	32.50+/-	2.46
TL199	81	16.024+/-	1.015	.0853	22.47+/-	1.42
AU200M	79	1.876+/-	.231	1.0000	32.18+/-	3.96
TL200	81	21.230+/-	2.123	.0802	65.52+/-	6.55
TL200	81	11.586+/-	1.108	.0802	35.76+/-	3.42
PB200	82	6.068+/-	.200	.1910	7.10+/-	.23
TL201	81	9.480+/-	.495	.0316	31.57+/-	1.65
BI201	83	4.354+/-	.693	.3506	5.01+/-	.80
BI202	83	3.749+/-	.812	.2390	4.26+/-	.92
PB203	82	4.441+/-	2.231	.0477	13.01+/-	6.54
BI203	83	1.309+/-	.131	.1500	1.59+/-	.16
BI204	83	1.497+/-	.502	.0889	2.14+/-	.72
PO206	84	2.284+/-	.223	.1189	3.00+/-	.29

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1140-MEV XE-136 + AU-197

NUCLIDE A Z		EXPERIMENTAL YIELD(MB)		FRACTION INDEPENDENT	CALCULATED MASS YIELD(MB)	
EXPERIMENT 95AU		1140-MEV XE-136 + AU-197				
NA 24	11	1.220+/-	.269	.8772	13.55+/-	2.99
MG 28	12	.910+/-	.094	.9193	29.77+/-	3.07
CA 47	20	.824+/-	.141	.8757	9.29+/-	1.59
SC 48	21	.817+/-	.068	1.0000	4.64+/-	.39
MN 52	25	2.931+/-	.774	.9645	12.97+/-	3.43
CO 56	27	4.819+/-	2.109	.9985	35.49+/-	15.53
CO 57	27	.382+/-	.404	.9912	1.80+/-	1.91
CO 58	27	.493+/-	.226	1.0000	1.72+/-	.79
FE 59	26	2.014+/-	.201	.6851	4.49+/-	.45
CO 60	27	1.810+/-	.362	1.0000	4.99+/-	1.00
AS 74	33	.538+/-	.032	1.0000	1.64+/-	.10
BR 82	35	3.886+/-	.083	1.0000	12.71+/-	.27
RB 83	37	1.140+/-	.182	.9884	4.57+/-	.73
SR 85	38	1.097+/-	.101	.9479	5.11+/-	.47
KR 88	36	2.951+/-	.340	.8815	37.03+/-	4.37
V 88	39	1.955+/-	.159	.6814	5.58+/-	.45
ZR 89	40	.638+/-	.064	.9205	4.76+/-	.48
Y 90M	39	5.262+/-	.586	1.0000	14.81+/-	1.65
SR 91	38	8.881+/-	.340	.7826	33.69+/-	1.29
SR 92	38	5.323+/-	.459	.8356	33.53+/-	2.89
MO 93M	42	1.186+/-	.151	1.0000	18.51+/-	2.36
ZR 95	40	12.710+/-	1.450	.7218	31.63+/-	3.61
TC 95M	43	1.012+/-	.749	1.0000	23.23+/-	17.19
NB 96	41	6.023+/-	.577	1.0000	16.72+/-	1.60
TC 96	43	.481+/-	.486	1.0000	5.65+/-	5.70
ZR 97	40	6.713+/-	.860	.8305	39.88+/-	5.11
MO 99	42	15.761+/-	1.244	.6563	29.62+/-	2.34
RH101M	45	1.180+/-	.193	1.0000	14.79+/-	2.41
RU103	44	22.311+/-	3.584	.5083	31.49+/-	5.06
RU105	44	13.650+/-	1.081	.6989	31.37+/-	2.48
RH105	45	21.820+/-	.332	.7864	49.72+/-	.76
AG105	47	.551+/-	.120	.9417	13.93+/-	3.04
RH106M	45	7.366+/-	.262	1.0000	20.33+/-	.72
AG106M	47	7.130+/-	1.281	1.0000	95.42+/-	17.14
AG110M	47	5.472+/-	.161	1.0000	16.06+/-	.47
IN110M	49	1.443+/-	.429	1.0000	42.01+/-	12.48
PD111M	46	6.156+/-	3.301	1.0000	25.73+/-	13.80
PD112	46	7.211+/-	1.004	.8144	36.20+/-	5.04
SB113	50	3.910+/-	.931	.9043	73.76+/-	17.57
IN114M	49	5.214+/-	.549	1.0000	19.00+/-	2.00
CD117M	48	1.939+/-	.741	1.0000	11.40+/-	4.36
SB118M	51	6.106+/-	.229	1.0000	32.25+/-	1.21
TE119M	52	3.862+/-	.451	1.0000	44.65+/-	5.21
SB120M	51	9.788+/-	.979	1.0000	29.57+/-	2.96
TE121	52	6.755+/-	1.249	.8939	26.93+/-	4.98
TE121M	52	7.972+/-	3.277	1.0000	35.56+/-	14.62
I 121	53	4.822+/-	2.102	.9097	72.15+/-	31.45
SB122	51	13.240+/-	.255	1.0000	38.01+/-	.73
TE123M	52	17.080+/-	7.209	1.0000	48.82+/-	20.61
I 123	53	19.940+/-	12.210	.9059	99.64+/-	61.01
SB124	51	10.090+/-	1.425	1.0000	45.72+/-	6.46
I 124	53	8.254+/-	2.247	1.0000	31.89+/-	8.68
SB125	51	4.520+/-	1.431	.8266	25.72+/-	8.14

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SB126	51	3.252+/-	.754	1.0000	38.62+/-	8.95
I 126	53	19.800+/-	2.462	1.0000	54.92+/-	6.83
SB127	51	2.602+/-	.052	.9602	58.10+/-	1.15
XE127	54	30.380+/-	.819	.9351	97.53+/-	2.63
CS127	55	17.220+/-	10.570	.8667	141.41+/-	86.80
SB128	51	1.461+/-	.146	.9544	72.09+/-	7.20
BA128	56	3.109+/-	.686	.9118	74.62+/-	16.47
TE129M	52	6.914+/-	1.094	1.0000	109.19+/-	17.28
CS129	55	27.250+/-	2.725	.8834	95.99+/-	9.60
BA129	56	37.790+/-	15.140	.8814	438.35+/-	175.62
I 130	53	17.800+/-	2.488	1.0000	116.56+/-	16.29
TE131M	52	4.450+/-	2.534	1.0000	342.69+/-	195.14
I 131	53	27.750+/-	1.213	.9702	300.11+/-	13.12
BA131	56	46.751+/-	2.238	.8524	191.83+/-	9.18
CS132	55	23.120+/-	8.446	1.0000	65.16+/-	23.80
LA132	57	10.390+/-	.133	.9609	100.41+/-	1.29
CE132	58	4.405+/-	1.124	.9354	270.41+/-	69.00
I 133	53	24.560+/-	5.817	.7221	28.70+/-	6.80
XE133M	54	36.970+/-	3.697	1.0000	302.38+/-	30.24
I 134	53	18.830+/-	8.470	.8858	26.26+/-	11.81
CS134	55	39.720+/-	5.883	1.0000	167.48+/-	24.81
CS134M	55	24.850+/-	2.485	1.0000	104.78+/-	10.48
CE134	58	33.949+/-	13.759	.8937	426.98+/-	173.05
I 135	53	16.250+/-	1.496	.9537	37.76+/-	3.48
XE135	54	408.298+/-	71.260	.8843	684.74+/-	119.51
BA135M	56	41.860+/-	4.186	1.0000	123.53+/-	12.35
LA135	57	56.939+/-	15.080	.9705	176.31+/-	46.69
CE135	58	9.332+/-	.613	.8606	63.30+/-	4.14
CS136	55	54.040+/-	.910	1.0000	566.21+/-	9.54
CS136	55	54.040+/-	.910	1.0000	326.48+/-	5.50
CS137	55	178.802+/-	71.241	.4257	185.43+/-	73.88
CE137M	58	15.300+/-	4.052	1.0000	55.35+/-	14.66
PR138M	59	9.988+/-	1.684	1.0000	63.29+/-	10.67
BA139	56	17.520+/-	.550	.8828	212.92+/-	6.68
BA139	56	17.520+/-	.550	.3005	10.06+/-	.57
CE139	58	39.740+/-	.779	.8447	92.58+/-	1.82
NDJ39M	60	5.895+/-	.278	1.0000	88.83+/-	4.19
BA140	56	5.514+/-	.335	.9117	139.65+/-	8.47
BA140	56	5.514+/-	.335	.5873	5.83+/-	.35
LA140	57	6.163+/-	.431	1.0000	36.67+/-	2.56
CE141	58	17.030+/-	1.592	.9082	54.01+/-	5.05
PR142	59	20.050+/-	5.570	1.0000	55.78+/-	15.50
PM144	61	10.500+/-	.741	1.0000	46.41+/-	3.27
PR145	59	1.022+/-	.595	.8072	4.69+/-	2.73
EU145	63	3.721+/-	.795	.9412	186.50+/-	39.85
PM146	61	4.288+/-	2.219	1.0000	12.22+/-	6.33
EU146	63	6.053+/-	2.312	1.0000	144.36+/-	55.14
GD146	64	3.287+/-	1.306	.9573	749.77+/-	297.90
EU147	63	5.344+/-	.785	.9957	64.52+/-	9.48
GD147	64	2.321+/-	1.108	.9602	195.34+/-	93.25
PM148	61	1.957+/-	.894	1.0000	5.98+/-	2.73
PM148M	61	3.275+/-	1.004	1.0000	10.01+/-	3.07
EU148	63	5.526+/-	.255	1.0000	38.67+/-	1.78
EU149	63	12.680+/-	2.162	.9985	58.07+/-	9.90
GD149	64	5.177+/-	.127	.9716	87.26+/-	2.14
GD151	64	6.667+/-	2.344	.9852	37.46+/-	13.17
TB151	65	12.320+/-	1.226	.9188	292.04+/-	29.06
TB152	65	4.069+/-	4.428	.9507	50.07+/-	54.49
GD153	64	5.051+/-	.263	.9902	15.57+/-	.81
TB153	65	5.436+/-	1.401	.9669	38.75+/-	9.99
TB154	65	1.592+/-	1.203	1.0000	7.59+/-	5.73
TB154M	65	1.724+/-	1.318	1.0000	8.22+/-	6.28

TB155	65	8.034+/-	.826	.7588	26.95+/-	2.77
DY155	66	7.115+/-	.712	.8972	63.23+/-	6.32
EU156	63	7.748+/-	2.320	.9795	62.95+/-	18.85
TD156	65	2.886+/-	.604	1.0060	8.41+/-	1.76
ND160M	67	1.096+/-	.011	1.3000	3.94+/-	.04
ER160	68	2.750+/-	1.186	.8627	24.97+/-	10.77
ER161	68	10.410+/-	1.041	.8429	54.93+/-	5.49
TM165	69	16.950+/-	2.235	.7401	46.35+/-	6.11
VB166	70	10.270+/-	.998	.8217	55.46+/-	5.39
VB169	70	22.640+/-	2.166	.9800	63.11+/-	6.04
LU169	71	12.991+/-	22.850	.8885	62.27+/-	109.54
LU170	71	12.080+/-	.921	.9680	44.49+/-	3.39
HF170	72	6.478+/-	1.698	.8710	67.33+/-	17.65
ER171	68	2.556+/-	.572	.9206	87.44+/-	19.56
LU171	71	12.190+/-	1.222	.9605	35.66+/-	3.57
HF172	72	12.700+/-	2.766	.8283	47.79+/-	10.41
HF173	72	15.101+/-	3.448	.8979	45.97+/-	10.50
TA173	73	11.000+/-	5.287	.8641	87.45+/-	42.03
VB175	70	6.642+/-	1.490	.9002	97.83+/-	21.95
HF175	72	28.990+/-	10.570	.9138	73.22+/-	26.70
TA175	73	17.691+/-	1.769	.7871	54.64+/-	5.46
TA176	73	18.250+/-	1.228	.8455	47.83+/-	3.22
TA177	73	26.060+/-	2.606	.7795	56.47+/-	5.65
W 177	74	27.820+/-	2.782	.7913	103.90+/-	10.39
TA178M	73	7.538+/-	.754	1.0000	21.33+/-	2.13
W 178	74	11.760+/-	1.467	.7314	29.90+/-	3.73
HF179M	72	.528+/-	.095	1.0000	4.44+/-	.80
HF180M	72	.664+/-	.299	1.0000	10.13+/-	4.57
HF181	72	.214+/-	.375	.9153	6.15+/-	10.77
RE181	75	19.440+/-	4.216	.8198	50.34+/-	10.92
TA182	73	3.201+/-	.913	1.0000	34.60+/-	9.86
RE182	75	40.410+/-	4.861	.9642	108.91+/-	13.10
RE182M	75	7.948+/-	1.611	1.0000	22.22+/-	4.50
OS182	76	84.820+/-	32.820	.8016	333.85+/-	129.18
TA183	73	23.630+/-	7.665	.9385	460.07+/-	149.24
RE183	75	31.640+/-	12.160	.8982	79.80+/-	30.67
OS183	76	16.440+/-	2.227	.7995	46.90+/-	6.35
OS183M	76	6.114+/-	.173	1.0000	21.82+/-	.62
TA184	73	3.034+/-	.343	.9262	127.05+/-	14.38
RE184M	75	10.380+/-	.562	1.0000	33.24+/-	1.80
IR184	77	12.330+/-	5.535	.8297	63.27+/-	28.40
OS185	76	36.640+/-	3.869	.9379	94.75+/-	10.01
IR185	77	13.660+/-	3.737	.8387	48.01+/-	13.13
IR186	77	15.780+/-	1.873	1.0000	50.86+/-	6.04
IR186M	77	11.160+/-	3.257	1.0000	35.97+/-	10.50
PT186	78	38.069+/-	20.430	.8490	261.76+/-	140.47
W 187	74	5.706+/-	1.430	.9358	356.39+/-	89.32
IR187	77	65.590+/-	10.890	.8035	148.33+/-	24.63
PT187	78	46.151+/-	22.171	.7958	187.89+/-	90.26
IR188	77	15.250+/-	3.687	1.0000	42.55+/-	10.29
IR188	77	23.850+/-	1.235	1.0000	66.54+/-	3.45
PT188	78	20.250+/-	.463	.7357	54.65+/-	1.25
PT189	78	146.397+/-	45.760	.6937	303.29+/-	94.80
IR190	77	6.958+/-	1.960	1.0000	27.91+/-	7.86
IR190	77	6.958+/-	1.960	1.0000	29.89+/-	8.42
IR190M	77	23.960+/-	1.484	1.0000	96.09+/-	5.95
PT191	78	88.171+/-	17.919	.7397	188.83+/-	38.38
AU191	79	51.690+/-	7.962	.7664	130.48+/-	20.10
IR192	77	7.385+/-	.318	1.0000	70.72+/-	3.04
MG192	80	9.625+/-	.962	.8056	41.38+/-	4.14
AU193	79	65.110+/-	7.325	.8666	156.63+/-	17.62
MG193M	80	9.970+/-	4.223	1.0000	37.65+/-	15.95

IR194M	77	6.934+/-	.368	1.0000	263.27+/-	13.96
IR194M	77	6.934+/-	.368	1.0000	23.79+/-	1.26
AU194	79	46.590+/-	1.684	1.0000	143.59+/-	5.19
IR195M	77	29.960+/-	7.187	1.0000	312.19+/-	74.89
PT195M	78	97.720+/-	18.380	1.0000	153.86+/-	28.94
AU195	79	77.360+/-	12.200	.8695	261.32+/-	41.21
AU195	79	77.360+/-	12.200	.9983	295.52+/-	46.61
HG195M	80	17.340+/-	2.047	1.0000	47.97+/-	5.66
AU196	79	194.300+/-	26.400	1.0000	368.47+/-	50.07
AU196M	79	68.110+/-	7.240	1.0000	378.67+/-	40.25
PT197	78	22.070+/-	16.580	.9854	131.39+/-	98.71
TL197	81	34.370+/-	2.433	.6761	66.58+/-	4.71
AU198	79	301.400+/-	19.360	1.0000	571.57+/-	36.71
AU198M	79	37.330+/-	2.971	1.0000	621.80+/-	49.49
TL198	81	37.899+/-	4.697	.7388	77.44+/-	9.60
TL198M	81	13.710+/-	3.725	1.0000	37.92+/-	10.30
TL198M	81	13.710+/-	3.725	1.0000	690.08+/-	187.49
PB198	82	4.273+/-	.427	.7731	12.86+/-	1.29
AU199	79	110.049+/-	27.580	.9804	412.83+/-	103.46
TL199	81	16.550+/-	6.478	.5830	29.24+/-	11.45
AU200M	79	5.849+/-	7.497	1.0000	484.79+/-	621.38
TL200	81	20.219+/-	5.621	.8957	68.26+/-	18.98
TL200	81	10.760+/-	.878	1.0000	40.56+/-	3.31
PB200	82	4.262+/-	2.936	.6376	7.55+/-	5.20
TL201	81	5.445+/-	1.585	.7197	20.86+/-	6.07
TL201	81	5.445+/-	1.585	.9896	9.70+/-	2.82
PB201	82	11.570+/-	1.157	.6541	21.47+/-	2.15
TL202	81	2.459+/-	.232	1.0000	20.98+/-	1.98
TL202	81	2.459+/-	.232	1.0000	3.72+/-	.35
PB202M	82	4.455+/-	1.521	1.0000	14.65+/-	5.00
PB203	82	7.174+/-	.717	.8034	24.96+/-	2.50
BI203	83	5.167+/-	2.067	.5840	8.33+/-	3.33
BI204	83	3.798+/-	.233	.7295	8.27+/-	.51
BI205	83	4.832+/-	2.278	.5256	9.30+/-	4.38
BI206	83	1.306+/-	.884	1.0000	6.66+/-	4.51
BI206	83	3.621+/-	.900	1.0000	18.47+/-	4.59
PO206	84	1.658+/-	.135	.6178	2.88+/-	.23
PO207	84	1.044+/-	.104	.5715	1.92+/-	.19

EXPERIMENT 96AU

1140-MEV KE-136 + AU-197

NA 24	11	1.160+/-	.116	.8964	13.16+/-	1.32
MG 28	12	.987+/-	.015	.9193	32.29+/-	.49
AS 72	33	4.261+/-	.343	1.0000	23.00+/-	1.85
BR 82	35	4.300+/-	.203	1.0000	14.06+/-	.67
BR 84M	35	2.870+/-	.314	1.0000	18.34+/-	2.01
V 86M	39	.538+/-	.836	1.0000	5.58+/-	8.67
KR 88	36	3.110+/-	1.365	.8815	44.05+/-	17.13
RB 88	37	9.082+/-	.336	1.0000	37.64+/-	1.39
RB 89	37	5.834+/-	.014	.8323	29.57+/-	.07
V 90M	39	4.974+/-	.497	1.0000	14.00+/-	1.40
SR 91	38	8.378+/-	.316	.7913	32.14+/-	1.21
SR 92	38	5.203+/-	.520	.8357	32.78+/-	3.28
V 92	39	9.381+/-	1.650	.9748	28.71+/-	5.05
MO 93M	42	.748+/-	.193	1.0000	11.67+/-	3.02
V 94	39	5.744+/-	.574	.8150	27.22+/-	2.72
NB 96	41	8.117+/-	1.096	1.0000	22.53+/-	3.04
ZR 97	40	6.645+/-	.664	.8306	39.48+/-	3.95
MO101	42	10.509+/-	.322	.7684	36.25+/-	1.11
TC104	43	8.222+/-	.822	.8034	35.15+/-	3.51
RU105	44	12.001+/-	3.659	.7863	31.03+/-	9.46
RH105	45	19.588+/-	3.700	.9626	54.64+/-	10.32

RH106M	45	5.940+/-	1.534	1.0000	16.39+/-	4.15
RH108B	45	5.734+/-	2.678	1.0000	20.99+/-	9.80
IN110M	49	3.711+/-	.978	1.0030	108.02+/-	28.46
CD111M	48	4.286+/-	.429	1.0000	17.81+/-	1.78
SB113	51	3.252+/-	1.455	.9547	609.64+/-	272.74
IN116M	49	7.380+/-	.578	1.0000	20.36+/-	1.60
SB116M	51	10.117+/-	2.562	1.0000	155.13+/-	39.28
IN117	49	6.190+/-	1.306	1.0000	17.98+/-	3.79
SB118M	51	6.342+/-	1.236	1.0000	33.50+/-	6.53
TE119M	52	3.493+/-	.050	1.0000	40.38+/-	.57
SB120B	51	10.695+/-	1.403	1.0000	32.31+/-	4.24
SB120M	51	1.977+/-	.318	1.0000	5.97+/-	.96
I 120M	53	.783+/-	.058	1.0000	26.89+/-	2.01
I 121	53	4.494+/-	.505	.9760	72.14+/-	8.10
XE121	54	2.078+/-	.066	.9542	274.81+/-	8.78
SB122	51	11.055+/-	.445	1.0000	31.74+/-	1.28
I 123	53	27.202+/-	6.643	.9831	147.50+/-	36.02
XE123	54	3.172+/-	1.649	.9323	71.94+/-	37.40
XE125	54	23.861+/-	3.000	.9662	163.45+/-	20.55
I 126	53	25.525+/-	3.323	1.0000	70.80+/-	9.22
BA126	56	1.135+/-	.302	.9537	166.66+/-	44.42
SB128	51	.895+/-	.100	.9303	1.39+/-	.16
I 128	53	13.378+/-	3.048	1.0000	44.24+/-	10.08
BA128	56	4.221+/-	.817	.9311	103.45+/-	20.02
SB129	51	1.979+/-	.198	.9028	2.76+/-	.28
CS129	55	24.065+/-	2.406	.9789	93.93+/-	9.39
BA129	56	18.816+/-	3.292	.9266	229.46+/-	40.15
I 130	53	17.103+/-	4.854	1.0000	112.00+/-	31.78
I 130M	53	8.573+/-	1.183	1.0000	56.14+/-	7.74
CS130	55	1.099+/-	.227	1.0000	3.44+/-	.71
TE131M	52	6.898+/-	.322	1.0000	10.43+/-	.49
BA131M	56	17.011+/-	1.701	1.0000	81.89+/-	8.19
LA131	57	9.374+/-	.278	.9389	167.26+/-	4.97
TE132	52	12.629+/-	1.070	.9296	21.13+/-	1.79
I 132	53	23.676+/-	5.722	1.0000	62.75+/-	15.17
I 132M	53	28.293+/-	2.829	1.0000	74.99+/-	7.50
LA132	57	7.801+/-	1.184	.9945	78.02+/-	11.84
LA132M	57	7.791+/-	.677	1.0000	78.36+/-	6.81
XE133M	54	23.455+/-	2.346	1.0000	191.84+/-	19.18
BA133M	56	17.659+/-	2.928	1.0000	51.65+/-	8.56
TE134	52	4.193+/-	.963	.9907	43.29+/-	9.94
I 134	53	21.289+/-	4.210	.9724	32.60+/-	6.45
CS134M	55	18.651+/-	1.169	1.0000	78.64+/-	4.93
I 135	53	9.276+/-	1.198	.9537	21.55+/-	2.78
XE135M	54	76.762+/-	6.143	1.0000	145.57+/-	11.65
BA135M	56	37.419+/-	3.742	1.0000	110.43+/-	11.04
CE135	58	33.879+/-	3.388	.9444	252.17+/-	25.22
CS136	55	45.459+/-	2.287	1.0000	274.64+/-	13.82
PR136	59	5.763+/-	1.433	1.0000	117.96+/-	29.34
CE137M	58	20.180+/-	.211	1.0000	73.01+/-	.76
XE138	54	6.881+/-	1.162	.9750	25.67+/-	4.33
CS138	55	19.821+/-	1.224	.8399	26.21+/-	1.62
PR138M	59	10.170+/-	.931	1.0000	64.44+/-	5.90
BA139	56	14.608+/-	.890	.4267	21.39+/-	1.30
ND139M	60	4.477+/-	.448	1.0000	67.46+/-	6.75
LA140	57	7.274+/-	.596	1.0000	43.29+/-	3.54
PM140M	61	3.241+/-	.324	1.0000	157.66+/-	15.77
TD152	65	4.388+/-	.437	.9918	56.33+/-	5.63
TD153	65	6.092+/-	.821	.9953	44.70+/-	6.03
SM155	62	1.523+/-	.152	.9021	30.17+/-	3.02
DY155	66	7.641+/-	.764	.9736	73.69+/-	7.37
HO155	67	9.403+/-	17.026	.9516	573.44+/-	1038.30

MC156	67	2.629+/-	.866	.9114	66.97+/-	22.05
MC157	67	16.618+/-	1.621	1.0000	229.91+/-	22.43
MC160	67	1.909+/-	.301	1.0000	6.86+/-	1.08
ER160	68	3.806+/-	.711	.8628	34.56+/-	6.46
ER161	68	10.264+/-	1.026	.9480	60.51+/-	6.09
TB162	65	23.157+/-	2.316	1.0000	324.27+/-	32.43
TM162	69	18.650+/-	3.171	1.0000	276.18+/-	46.95
TM163	69	2.769+/-	.277	.9140	20.78+/-	2.08
TM166	69	11.497+/-	7.283	1.0000	34.46+/-	21.83
YB166	70	25.232+/-	2.692	.8218	136.27+/-	14.54
LU167	71	11.810+/-	.246	.8873	166.33+/-	3.47
LU168	71	12.270+/-	1.227	1.0000	106.57+/-	10.66
LU169	71	12.469+/-	.326	.9775	65.77+/-	1.72
LU170	71	22.420+/-	2.182	.9957	84.94+/-	8.27
LU171	71	13.084+/-	1.496	.9946	39.64+/-	4.53
HF171	72	9.099+/-	2.216	.8271	52.00+/-	12.66
TA173	73	11.745+/-	.978	.9364	101.17+/-	8.43
TM174	69	3.241+/-	.324	.9309	163.30+/-	16.33
TA174	73	9.444+/-	.944	.9410	50.11+/-	5.01
TA175	73	14.352+/-	1.435	.9293	52.34+/-	5.23
W 175	74	1.629+/-	.163	.9028	18.72+/-	1.87
TA176	73	23.560+/-	2.420	.9725	71.02+/-	7.29
W 176	74	6.655+/-	.653	.8560	41.44+/-	4.07
HF177M	72	12.034+/-	1.203	1.0000	45.02+/-	4.50
RE177	75	5.629+/-	.563	.8942	92.18+/-	9.22
RE178	75	6.864+/-	.686	.8822	59.09+/-	5.91
RE179	75	9.169+/-	.795	.8674	46.94+/-	4.07
HF180M	72	6.244+/-	.624	1.0000	95.26+/-	9.53
HF182M	72	7.516+/-	.502	1.0000	551.78+/-	36.86
RE182	75	75.256+/-	15.892	.9953	209.35+/-	44.21
RE182	75	47.568+/-	15.350	.9953	132.33+/-	42.70
IR182	77	13.810+/-	6.630	.9078	247.14+/-	118.66
OS183	76	25.924+/-	4.401	.9489	87.78+/-	14.90
OS183M	76	5.378+/-	.303	1.0000	19.19+/-	1.08
IR183	77	83.516+/-	33.359	.9054	783.66+/-	313.03
IR184	77	10.179+/-	8.048	.9292	58.50+/-	46.25
TA185	73	4.139+/-	1.901	.9460	437.95+/-	201.12
IR185	77	9.862+/-	.112	.9623	39.77+/-	.45
PT185A	78	.687+/-	.157	.9069	9.07+/-	2.19
PT185B	78	1.282+/-	.363	1.0000	18.66+/-	5.29
IR186	77	20.102+/-	1.988	1.0000	64.79+/-	6.41
IR186M	77	6.439+/-	.644	1.0000	20.75+/-	2.08
PT186	78	5.770+/-	.577	.9175	42.88+/-	4.29
AU186	79	3.931+/-	.652	.9296	169.93+/-	28.20
IR187	77	22.833+/-	3.053	.9633	61.90+/-	8.28
FE188M	75	6.036+/-	2.065	1.0000	116.22+/-	39.75
IR188	77	18.238+/-	5.212	1.0000	50.88+/-	14.54
IR188	77	17.953+/-	26.256	1.0000	50.09+/-	73.25
AU188	79	2.786+/-	2.487	.8789	26.99+/-	24.09
AU189	79	64.382+/-	5.800	.8831	369.05+/-	33.25
OS190M	76	1.910+/-	.178	1.0000	25.44+/-	2.37
IR190	77	55.438+/-	13.604	1.0000	222.33+/-	54.56
IR190M	77	18.602+/-	1.865	1.0000	74.60+/-	7.48
AU190	79	27.206+/-	20.841	.9014	106.43+/-	81.53
HG190	80	2.212+/-	.221	.8864	30.57+/-	3.06
AU191	79	28.317+/-	5.069	.9401	87.68+/-	15.70
HG191	80	9.496+/-	1.384	.9101	73.99+/-	10.79
AU192	79	14.370+/-	14.807	1.0000	40.78+/-	42.02
HG192	80	8.268+/-	.517	.8806	38.86+/-	2.43
AU193	79	46.481+/-	11.599	.9836	126.90+/-	31.67
HG193M	80	13.070+/-	2.351	1.0000	49.36+/-	8.88
AU194	79	38.815+/-	.762	1.0000	119.63+/-	2.35

TL194M	81	2.993+/-	.336	1.0000	20.42+/-	2.29
HG195M	80	21.122+/-	.254	1.0000	58.43+/-	.70
TL195	81	10.307+/-	2.910	.8961	41.57+/-	11.74
AU196	79	163.660+/-	30.652	1.0000	310.37+/-	58.13
AU196M	79	45.970+/-	10.553	1.0000	255.58+/-	58.67
TL196M	81	5.015+/-	1.618	1.0000	16.90+/-	5.45
PB196	82	1.804+/-	1.083	.9070	14.84+/-	8.90
PT197M	78	5.359+/-	1.948	1.0000	296.83+/-	107.91
PB197M	82	8.100+/-	.914	1.0000	45.16+/-	5.09
AU198	79	312.710+/-	46.926	1.0000	593.02+/-	88.99
AU198M	79	30.459+/-	4.830	1.0000	507.35+/-	80.46
TL198	81	13.165+/-	3.687	.9485	34.54+/-	9.67
TL198M	81	12.393+/-	4.637	1.0000	34.28+/-	12.83
TL198M	81	12.393+/-	4.637	1.0000	623.79+/-	233.40
PB198	82	2.237+/-	5.232	.8700	7.58+/-	17.72
BI198	83	2.990+/-	.589	1.0000	37.44+/-	7.38
HG199M	80	11.196+/-	1.676	1.0000	76.13+/-	11.40
HG199M	80	11.196+/-	1.676	1.0000	17.63+/-	2.64
TL199	81	15.028+/-	6.966	.8868	40.38+/-	18.72
TL199	81	15.028+/-	6.966	.9992	156.47+/-	72.53
PB199	82	26.559+/-	6.056	.8713	71.41+/-	16.28
AU200	79	11.350+/-	3.081	1.0000	139.36+/-	37.83
TL200	81	36.744+/-	11.968	1.0000	138.49+/-	45.11
PD201	84	30.754+/-	3.075	.8700	257.20+/-	25.72
PB202M	82	4.407+/-	.441	1.0000	14.50+/-	1.45
PB203	82	6.301+/-	.490	.9689	26.43+/-	2.06
BI203	83	15.834+/-	1.583	.8228	35.95+/-	3.60
PD203	84	18.011+/-	4.076	.8367	60.57+/-	13.71
PB204M	82	1.556+/-	.451	1.0000	10.07+/-	2.92
BI204	83	3.485+/-	.256	.9486	9.86+/-	.72
AT208	85	9.666+/-	.705	.8267	22.03+/-	1.61
FR212	87	2.613+/-	.261	1.0000	7.77+/-	.78

XBL 776-9016

mass yield has been made at least 25%.

The nuclides ^{24}Na and ^{28}Mg appear in the results for all the projectiles used. They are not derived from some impurity in the target or from contamination because consistent yields are obtained from two experiments using the same projectile and energy (cf., experiments 95AU and 96AU, 53AU and 54AU). The mass-yield integrations performed for these two isotopes stand on very shaky grounds because radiochemical experiments cannot obtain enough data points in this mass region to allow definition of the Gaussian distribution of isobars. The integration has been performed by using the same parameters used at higher masses where more information is available. The integrated mass-yield results for the lightest nuclides should only be used with great caution.

In table 14 are the parameters that were used to achieve the fitting and the yields expressed in millibarns for each component and for a total. In some cases the paucity of data necessitated obtaining one component's parameters from those of its corresponding mate, but this was avoided whenever possible.

B. X-Ray Spectra

The use of X-ray spectra to qualitatively analyze radioactive samples has already been mentioned. In addition, it was found that X-ray spectra of bombarded target foils provided valuable and rapid semi-quantitative information on the distribution of product yields.

A 0.5-cm^3 intrinsic germanium solid-state detector was coupled to a pulse height analyzer providing 1000 or 2000 channels of storage

Table 14. Parameters for Gaussian Fitting and Mechanism Yields

	Height	Center	FWHM	Yield (mb)
252-MeV Ne-20 + Au-197				
Light Elastic	140.	20.	3.	450.
Heavy Elastic	140.	196.5	3.	450.
Light Inelastic	20.	23.	10.	225.
Heavy Inelastic	20.	189.	13.	290.
Fission/2	30.	107.5	48.	1530.
Total		(Geometric = 1900)		2240.
336-MeV Ar-40 + Au-197				
Light Elastic	180.	40.	3.	575.
Heavy Elastic	180.	196.5	3.	575.
Light Inelastic	30.	40.5	10.	335.
Heavy Inelastic	27.	187.	12.	360.
Fission/2	12.5	117.5	75.	1000.
Total		(Geometric = 1600)		1920.
705-MeV Kr-84 + Au-197				
Light Elastic	300.	84.	3.	960.
Heavy Elastic	300.	196.3	3.	960.
Light Inelastic	45.	90.5	39.	1960.
Heavy Inelastic	40.	187.	43.	1920.
Fission/2	12.5	105.	5.	65.
Total		(Geometric = 1900)		2900.

Table 14. Cont'd.

	Height	Center	FWM	Yield (mb)
730-MeV Kr-86 + Au-197				
Light Elastic	350.	84.	3.	1120.
Heavy Elastic	350.	196.5	3.	1120.
Light Inelastic	80.	84.	32.	2860.
Heavy Inelastic	60.	188.	40.	2680.
Fission/2	12.5	103.	10.	135.
Total		(Geometric = 1900)		3890.
620-MeV Kr-86 + Au-197				
Light Elastic	320.	85.	3.	1020.
Heavy Elastic	300.	196.5	3.	960.
Light Inelastic	55.	85.	22.	1350.
Heavy Inelastic	45.	189.	24.	1200.
Fission/2	3.	132.5	30.	95.
Total		(Geometric = 1500)		2360.
1140-MeV Xe-136 + Au-197				
Light Elastic	500.	135.	3.	1600.
Heavy Elastic	500.	197.5	3.	1600.
Light Inelastic	150.	133.	18.	3020.
Heavy Inelastic	125.	188.	23.	3210.
Fission/2	17.5	98.	23.	430.
Total		(Geometric = 2100)		5145.

and adjusted for approximately 100 eV per channel. The detector resolution is given in table 7. The channel-to-energy calibration was determined using several isotopic standards chosen from ^{137}Cs (31.8 and 32.2 keV), ^{241}Am (59.5 keV), ^{207}Bi (72.8 and 75.0 keV), ^{109}Cd (88.0 keV), ^{57}Co (122.1 keV).

The detector efficiency was not ascertained because it was not deemed worthwhile to attempt to determine the absolute disintegration rates. Many decaying nuclides, both original products and radioactive descendants, contribute to any one X-ray photopeak. Each nuclide has its own characteristic half life and X-ray yield, and it would be very difficult to unravel the complex mixture. In addition, the low energy of X-rays makes them more vulnerable to absorption effects. X-rays of some elements (e.g., tantalum and samarium) may appear to be missing in some spectra because of low probability for X-ray emission during the decay process and/or low specific activity due to very long and very short isotopic half lives.

The most intense X-rays for any one element are the $K_{\alpha 1}$ and $K_{\alpha 2}$ lines, which are easily resolved in the spectrum at higher energies. Unfortunately, the $K_{\alpha 1}$ line of one element of high atomic number is very close in energy to the $K_{\alpha 2}$ line of the element one higher in atomic number, and the two lines overlap in the spectra. Assuming a smooth variation in yields with change in atomic number, one can still estimate quantities of the elements made. A more difficult problem occurs in the region of the K_{β} X-rays of Au and its immediate neighbors. Although the K_{β} X-rays are of low abundance (less than 30% relative to

the K_{α} abundance), the high yields of products in the neighborhood of the target allows these X-rays to overwhelm the K_{α} X-rays of similar energy belonging to lower yield elements, such as Pb and Bi. For such "hidden" elements, the K_{β} X-rays can serve to indicate their presence, but these lines are reduced in abundance, and their intensities are further diminished by the elements' low yields in the heavy-ion reactions.

Figure 39 displays the X-ray spectrum obtained from the target foil resulting from the reaction $705\text{-MeV } ^{84}\text{Kr} + ^{197}\text{Au}$. The high yields about the target element are readily apparent, and one sees the precipitous decline in yields above the target and the gradual descent below the maximum and visible down to the Ba X-rays or even lower. The products in the vicinity of the projectile are not readily visible because these elements have low fluorescence yields, are less likely to decay by K-capture leaving a vacancy in the electron shell, tend to undergo internal conversion less often, and are more likely to be neutron-rich than the products with higher atomic numbers. Visible in the spectrum are the L lines of gold, but these come almost completely from the fluorescence induced within the thick target foil by the contained radioactivity. This induced fluorescence also exaggerates the gold K X-rays in the spectrum.

IV. DISCUSSION

A. Observations on the Mass-Yield Distributions

The shapes of the mass-yield distributions exhibit many similarities even when different projectiles were used, and the basic characteristics of the participating reaction mechanisms are to be found in these common properties.

Table 15 lists some of the parameters of the nuclear reactions with gold. The experiments utilized thick gold targets, and the projectile energies actually ranged from the maximum value down to the Coulomb barrier. The maximum angular momentum was calculated for touching target and projectile spheres, and this value declines as the projectile beam loses energy while traversing the thick target foil. The maximum angular momentum increases with both the projectile mass and energy. The parameter E/B has been used to typify the degree of angular rotation that occurs during the deep-inelastic reactions.⁶³ For experiments conducted with Ar-40, Kr-84, Kr-86, and Xe-136, the maximum value of this parameter falls within a small range, and the minimum value is always one by definition.

A tall, narrow distribution of products is always found for mass and atomic numbers very close to those of the target and projectile nuclei. These distributions have a constant width irrespective of the projectile mass and energy. The total cross-sectional yield increases with projectile mass. This type of distribution is attributed to the

quasi-elastic transfer mechanism. The slight glancing collision responsible for this reaction mechanism is in accord with the lack of sensitivity to projectile mass, small degree of mass transfer and little nuclear excitation observed.

Two wider distributions representing the results of the deep-inelastic transfer mechanism are found for each of the plots. One component can be associated with the target and a second originates from the projectile. The width of the component originating from the gold target is slightly larger than the width of the accompanying projectile distribution. Nucleons tend to be transferred from the gold nucleus to the projectile, but the most likely reaction products involve the transfer of only several nucleons. The width of the distribution is so large that in the cases of krypton and xenon experiments symmetric division of mass can be achieved. Interestingly, the width decreases in going from krypton to xenon, reversing the earlier trend; this occurs despite the increase in average excitation energy. This may be attributed to the driving force toward symmetry (table 19). The deep-inelastic exit channel is the chief mechanism found for heavier-ion reactions and appears to have supplanted the fusion-fission mechanism observed in the argon and neon experiments. A radiochemical study⁶⁴ of the reaction $\text{Fe-56} + \text{U-238}$ very nicely shows the transition as the fusion-fission contribution declines and yields from the deep-inelastic transfer mechanism become more prominent. The width and the area of the deep-inelastic components can both be seen to increase as the Kr-86 beam energy is raised from 620 MeV to 730 MeV.

Table 15. Nuclear Reactions and Maximum Angular Momenta

Projectile	E_{lab} (MeV)	E^* (MeV)	$L_{maximum}$	E_{max}/B
$^{20}_{Ne}$	252	140	115	2.57
$^{40}_{Ar}$	336	131	163	1.89
$^{84}_{Kr}$	705	227	315	1.85
$^{86}_{Kr}$	730	236	325	1.88
$^{86}_{Kr}$	620	164	271	1.62
$^{136}_{Xe}$	1140	302	456	1.81

The rise in energy leads to both greater internal excitation and to longer contact between the target and projectile nuclei.

In several experiments an excess of yields was observed in the neighborhood of $A = 100$. This phenomenon is most visible in the results of $\text{Xe-136} + \text{Au-197}$ because of the minimal overlap with the projectile deep-inelastic component. The effect is somewhat visible when krypton is the projectile, but the fusion-fission distribution is too large for this to be seen (if it occurs) in the results of the Ar-40 and Ne-20 experiments. The mass for this component corresponds to fission of products in the neighborhood of the Au-197 target. The atomic number for the products before fission is about $Z = 84$. Such fission was observed in the heavy-ion reactions with a U-238 target,^{7,13} and it was also reported for $705\text{-MeV Kr-84} + \text{Bi-209}$.³¹ It has been called cascade fission,⁷ sequential fission^{19,21} and secondary fission.²⁹ Such fission has been observed using on-line solid-state detectors with gold targets.^{21,29} Further evidence for assigning this component to sequential fission can be found in the plots of calculated nuclidic independent yields versus displacement from the most probable atomic number. (This plotting method was discussed in an earlier section.) Yields for high- Z isotopes are less than would be expected by extrapolating from data obtained for lighter nuclides. Sequential fission is the cause of this diminution. Sequential fission is found for nuclides beyond the region of the closed nucleon shells found for lead. The height of fission barriers markedly drops as the atomic number increases beyond $Z = 82$,¹⁴ and this decreasing ability to withstand fission is responsible for the onset of sequential fission. This

fission is analogous to the cascade fission found for the the reaction 605-MeV Kr-84 + U-238.⁷

In using a Gaussian curve to model the mass-yield distribution of deep-inelastic reaction products, it was noted that a skewness existed in the data toward the direction of symmetric mass division. To account for this departure from symmetry, exponential tails were matched to the two Gaussian-shaped curves representing the deep-inelastic components; this was described in a prior section. Such a departure from Gaussian symmetry has been found for the reaction 712-MeV Kr-84 + Bi-209.⁶⁵ The enhancement of yields as symmetry in mass is approached may be due to the growth of a neck region between the two connected nuclei during the period of rotation. Nuclear viscosity effects could be the controlling factor limiting the rate of neck growth. The model of a Gaussian curve with exponential tailing in the direction of symmetric mass division has been used to fit all the experimental results, but the difference between inclusion or exclusion of tailing for the Ne-20 and Ar-40 experiments is slight.

The fusion-fission reaction mechanism provides the majority of the total yield when light ions (Ne-20 and Ar-40) react with the gold target in the range of 8.4 MeV per projectile nucleon down to the Coulomb barrier. The products result from the symmetric fission of the fused target-projectile system. The mid point of each distribution corresponds to the evaporation of very few nucleons. The widths of the distributions seem to be larger than might be expected from earlier results.^{15,16}

When heavier projectiles are utilized, this mechanism appears to be supplanted by deep-inelastic reactions. However, the mass-yield distribution obtained from the experiment 620-MeV Kr-86 + Au-197 very definitely shows the presence of a component that could arise from the symmetric fission of the fused target and projectile nuclei. A small nuclear potential well exists for the fusion of Kr-84 + Bi-209,¹² and a similarly small attractive well should be found for the analogous gold system. So it is entirely possible that the two colliding nuclei can be brought together and made to fuse. Especially because thick target experiments cover the energy range from the maximum to the Coulomb barrier, these investigations possess an advantage over solid-state detection methods which are limited to observing the results for one beam energy at a time. An alternative consideration must be the possibility of enough diffusion of nucleons during the deep-inelastic interaction that symmetry of mass is achieved. This latter possibility should be unlikely because nuclear diffusion is directly related to the projectile energy and symmetric yields are not markedly enhanced when the beam is 730-MeV Kr-86 or 705-MeV Kr-84.

The total cross-sectional yield obtained by summing the various components is to be compared with the geometric value obtained from,

$$\sigma = \pi R_0^2 (A_1^{1/3} + A_2^{1/3})^2 \int_B^{E_{\max}} \left(1 - \frac{B}{E}\right) dE ,$$

where the radius parameter R_0 has the value 1.44 fermis. Especially large discrepancies are found for the more massive projectiles.

Systematic error may be involved in the case of the Xe-136 yields as further problems with this projectile will be mentioned in the next section. In addition, the fitting procedure contains elements of judgment, and the uncertainty in the values derived may be 25% or worse in some cases.

Yields for very light nuclides (e.g., Na-24) consistently appear for all the experiments, but they cannot be fit into any reaction component. The origin of these nuclides is uncertain.

B. Gold Yields and Isomer Selection

Figure 40 contains a plot of the relative yields of gold nuclides obtained in the reaction of 336-MeV Ar-40 with a gold target. The yields have been corrected to independent yields by the methods earlier discussed. When possible, the yields for two states with the same mass number have been differentiated.

One observes the existence of a Gaussian distribution for the low-mass isotopes, and this distribution can be continued using the data points for metastable isomeric states. Similarly, another Gaussian curve describes the distribution of yields for the ground-state nuclides in the vicinity of the target, stable Au-197. What is responsible for this apparent factorization?

Comparing the two Gaussian curves, one finds that the curve made from the low-mass isotopes and high-spin metastable states has a larger width and is centered at a lower mass number than the corresponding parameters for the other curve. This suggests that more internal energy

is associated with the interactions that led to the first group of yields. In addition, the first group of yields fits well with the large set attributed to the consequences of the deep-inelastic transfer mechanism.

The gold isotopes contributing to the narrow Gaussian curve are members of a small set surrounding the target and projectile in both mass number and atomic number. The yields of this set decrease drastically as the mass number and/or atomic number moves away from the target or projectile origin. The yields very close to the origins are higher than those for any other reaction products. Earlier works have credited the quasi-elastic transfer mechanism as being responsible for the large yields about the target and projectile.

Table 16 tabulates properties of gold nuclides which are members of an isomeric pair. Examining the nuclear spins of the observed pairs, one finds that one member of the pair (the higher energy member) possesses a very large nuclear spin, and de-excitation of this high-spin level requires a high-multipole transition (e.g., E3 for ^{197m}Au and M4 for ^{196m}Au). The high-spin states occur because of the transfer of an unpaired proton hole from a $d_{3/2}$ level to the nearby $h_{11/2}$ level. Gold isotopes possessing an odd neutron can move an unpaired neutron hole from what is usually an $f_{5/2}$ level to an $i_{13/2}$ level. The coupling of the $h_{11/2}$ proton with the $i_{13/2}$ neutron yields the 12^- nuclear state seen in the even-A gold isotopes.^{66,67}

The quasi-elastic transfer reaction results from a peripheral collision between the target and projectile nuclei. As a result of

Table 16. Properties of Gold Isotopes

Isotope	Half Life	Nuclear Spin
Au-193g	17.6 hours	3/2+
Au-193m	3.9 seconds	11/2-
Au-195g	183 days	3/2+
Au-195m	30.5 seconds	11/2-
Au-196g	6.18 days	2-
Au-196m	9.7 hours	12-
Au-197g	Stable	3/2+
Au-197m	7.5 seconds	11/2-
Au-198g	2.70 days	2-
Au-198m	2.27 days	12-
Au-200g	48.4 minutes	1-
Au-200m	19 hours	12-

such a slight interaction, very little of the initial kinetic energy is transferred by the collision to internal energy modes. The excitation of the nuclei is adequate to allow emission of, at most, only a very few nucleons so that the final products are in close proximity to the original target or projectile nucleus. Also, the short duration of the glancing collision and the small overlap of the target and projectile nuclei during the nuclear interaction reduces the extent of nucleon transfer.⁶⁸ In the light of these characteristics, one can understand the quasi-elastic transfer mechanism which give rise to a narrow distribution of products only slightly removed from the projectile or target in mass number and atomic number.

Large impact parameters and high angular momentum l -waves are involved in the quasi-elastic reaction mechanism, but most of the incident angular momentum remains with the trajectories of the nuclei as they gently brush past each other and continue outward approximately towards the grazing angles. In addition, the effective mass involved in the minimal collision occurring is less than the reduced value calculated from the target and projectile masses because most of the nucleons are not subjected to a large impulse. So products derived from the quasi-elastic transfer mechanism should tend to possess a relatively small amount of angular momentum, and this is borne out by the yields of the low-spin members of gold isomer pairs.

The remaining l -wave components can contribute to the inelastic channel, and, in the cases of the heaviest projectiles, apparently all the cross section from central collisions goes into the

deep-inelastic mechanism. The alternate exit channels are compound-nucleus formation and fusion-fission, and these predominate when lighter projectiles are used.

Heavy-ion reactions can involve a large amount of angular momentum (see Table 15). Particle evaporation can carry away some of the angular momentum, but the angular momentum barriers inhibit emission of particles carrying much angular momentum. When the yrast line is approached and energetics forbid further particle emission, most of the remaining angular momentum is lost in a series of E2 gamma-ray transitions. The sequence of yrast levels traversed in the de-excitation of gold nuclei usually includes the high-spin level responsible for the isomeric states. This occurs because the preferred pathway goes through levels producing the smallest spin change coupled with the largest energy change.⁶⁹ The E2 transitions are even more favored than usual due to collective effects. Excited nuclei reaching a 12^- level described in table 16 are held up there because of the large spin change necessary to move to any lower energy level; these high-spin, low-energy levels act as angular momentum traps that capture any de-exciting nuclei funneled in their direction.

The conclusion is that in cases of gold isotopes with two distinguishable levels (e.g., ¹⁹⁶Au) most of the yield from the deep-inelastic reaction mechanism appears in the high-spin state and the quasi-elastic reaction yield goes into the low-spin state. This result should not be a strong function of energy, and a similar division of yields should be found to occur even if the high-spin state were to be the ground state; this last point will be covered later.

Figures 42 and 44 depict the calculated independent yields of gold nuclides resulting from the reactions 730-MeV Kr-86 + Au-197 and 1140-MeV Xe-136 + Au-197. Each distribution of yields again can be factored into two components, and a Gaussian curve has been fit to each component. The calculated independent yields for the reactions 252-MeV Ne-20 + Au-197 and 620-MeV Kr-86 + Au-197 are seen in figures 41 and 43, but the data are too sparse and poor to allow a good fit to be made for the deep-inelastic component. Table 17 lists the parameters of the Gaussian curves.

The parameters defining the curves fitting the yields derived from the quasi-elastic reaction mechanism are quite similar, except for the case of Xe-136 + Au-197. The centers of the distributions are all just below the origin of the stable gold target, and the widths are relatively narrow. These two facts point out the low degree of internal excitation involved in the quasi-elastic reaction mechanism. The properties for this reaction mechanism appear to be rather insensitive to projectile energy--compare the parameters for the two cases of using Kr-86 as the projectile.

Figure 45 contains a graph of the areas of the Gaussian curves for the quasi-elastic reaction component plotted as a function of the projectile mass number to the two-thirds power. The projectile surface and cross section are directly proportional to $A^{2/3}$ if the nucleus is spherical. The data points for all the experiments, with the exception of Xe-136, fall neatly on a straight line passing through the origin. One might well expect that the quasi-elastic yields should be related

Table 17. Parameters for Gaussian Fitting to AU Yields

Projectile	Quasi-Elastic			Deep-Inelastic		
	Center	FWHM	Area	Center	FWHM	Area
1140-MeV $^{136}_{54}\text{Xe}$	197.5 $\pm$ 0.0	2.24 $\pm$ 0.37	886.7 $\pm$ 50.4	194.6 $\pm$ 0.3	6.36 $\pm$ 2.13	375.2 $\pm$ 42.4
730-MeV $^{86}_{36}\text{Kr}$	196.8 $\pm$ 0.1	2.08 $\pm$ 0.62	458.7 $\pm$ 39.5	193.9 $\pm$ 0.2	7.07 $\pm$ 2.88	112.1 $\pm$ 5.4
620-MeV $^{86}_{36}\text{Kr}$	196.2 $\pm$ 0.2	2.64 $\pm$ 0.97	465.3 $\pm$ 28.2			
336-MeV $^{40}_{18}\text{Ar}$	196.6 $\pm$ 0.1	2.27 $\pm$ 0.82	263.6 $\pm$ 40.2	193.5 $\pm$ 0.2	5.81 $\pm$ 2.21	31.1 $\pm$ 2.7
252-MeV $^{20}_{10}\text{Ne}$	196.2 $\pm$ 0.1	2.12 $\pm$ 0.88	179.1 $\pm$ 21.3			

to the sum of the target and projectile radii since these are related to the area of overlap of two shells at the nuclear surfaces, but such a sum is strongly dominated by the gold radius, and the quasi-elastic yields will correspondingly be a weak function of the projectile radius. This is not to be found for the experimental data. Still, some geometrical interpretation is suggested by the relationship to the projectile cross-sectional area, but for now the explanation is lacking.

The data point for the Gaussian area from the Xe-136 reactions does not conform to the linear fit obtained for the remaining data. The reason for the discrepancy is not clear, but several suggestive points should be considered. The Xe-136 nucleus possesses a higher neutron-to-proton ratio than does Au-197, but the other projectiles used were more neutron-poor than the target. If the force driving toward charge-density equilibration is strong and rapid enough to be effective during the fast grazing collision, one has here a significant difference distinguishing the Xe-136 projectile. The center of the gold quasi-elastic isotopic distribution is located at a more neutron-rich value for the Xe-136 results than for the others, and this may be due to charge equilibration pushing a neutron from the rich projectile to the relatively deficient target nucleus. A second difference among the projectiles used is that the attractive pocket in the nuclear potential surface, which has been shrinking with the increase in projectile mass, has finally disappeared for the system Xe-136 + Au-197. But the question must be asked whether the quasi-elastic reaction mechanism is operative when the nuclear reaction system has reached the region of the attractive

pocket or if the fusion-fission and deep-inelastic channels will dominate, and the latter is more likely. Thirdly, as the neutron-proton asymmetry of the projectiles is increasing, so is the neutron skin on the edges of the nucleus. A simple calculation based on the neutron-proton difference and the nuclear surface area shows that the Xe-136 skin thickness is about 50% greater than that of Kr-86. The grazing collisions occur in the periphery of the nucleus, and perhaps the larger skin thickness is the reason for the apparent enhancement of the quasi-elastic yield. Lastly, the possibility that systematic error has entered the calculation of the yields from the Xe-136 + Au-197 reaction cannot be completely discounted.

Fewer results are available relative to the deep-inelastic mechanism, so conclusions derived from the data are substantially more tentative than was the case with the quasi-elastic reaction component. Yields obtained when using Ne-20 as the projectile were for quite neutron-deficient gold isotopes, and problems with very short half lives, unknown absolute gamma-ray abundances and large uncertainties precluded curve fitting. In the case of the 620-MeV Kr-86 + Au-197 experiment, the long time lapse between the end of bombardment and the start of measurements, the meager projectile beam intensity and the long length of bombardment which built up long-lived activities all worked to make more difficult the measurement of short-lived, neutron-deficient nuclides. One unsolved question concerns the inability to observe Au-196m and Au-198m. Both are relatively long-lived and were observed in the experiments using 730-MeV Kr-86.

The center of the Gaussian curve fitting the deep-inelastic independent yields appears to increase along with the mass of the projectile, and the highly neutron-deficient gold isotopes produced by using Ne-20 as the projectile supports this point. This is due to the rapid charge equilibration that occurs during the course of the deep-inelastic transfer reaction.⁷⁰ The hypothetical compound nucleus achieves a higher neutron-to-proton ratio as heavier projectiles are used with the gold target, and the increasing neutron richness should be reflected in the products of the deep-inelastic mechanism. This will also be influenced by the greater neutron and proton evaporation that should accompany higher excitation energies.

The Gaussian widths are quite similar regardless of the projectile used, and this occurs despite the greater maximum excitation energy achievable using the heavier projectiles. An intriguing hint of tailing on the low-A portion of the deep-inelastic isotopic distribution may be a part of the tailing used to model the entire distribution of deep-inelastic products.

A large portion of the cross section goes into fusion-fission for the cases of Ne-20 and Ar-40 bombardments, and very little cross section remains to go into the deep-inelastic reaction channel. The Kr-86 and Xe-136 induced reactions yield deep-inelastic products when any substantial overlap of target and projectile nuclear potentials occurs. Gold products are produced in greater yield by the Xe-136 projectile because of rapid charge equilibration occurring during the course of deep-inelastic reactions and the more favorable neutron-to-proton ratio of the

"compound" system.

Table 18 lists the yields of various isomeric pairs as obtained from the reaction of 1140-MeV Xe-136 with a thick Au target. One observes that the high-spin state is normally produced in greater yield, even if it is the ground state (Os-183, Ir-186). This proves that nuclear spin, and not energy of the level, is the crucial factor in determining which of two isomeric levels is more likely to result from the deep-inelastic reaction mechanism. The disparity of isomeric yields is reduced as the products become more removed in atomic number and/or mass number from the original target and projectile nuclei.

The yield of the ground state of Cs-134 should be mostly due to the quasi-elastic transfer mechanism that has been shown to favor low-spin nuclear levels. The discrepancy in expected relative yields for Re-182 is not resolved. Nor is it understood why for neighboring isomeric pairs (Re-182, Os-183, Re-184) the isomeric ratios are so different. Perhaps the nuclear levels play an important role in dividing up the yield.

The trends discussed here for products from the Xe-induced reactions also appear when other heavy-ion projectiles are used with a thick gold target.

Oganessian, et al.²² performed a radiochemical determination of the cross sections for transfer reaction products, including Au isotopes from the heavy-ion bombardments of gold targets. The projectiles used were 170-MeV C-12, 170-MeV Ne-22 and 270-MeV Ar-40. The targets were very thin, and very little projectile energy was lost in traversing

Table 18. Isomer Yields—1140-MeV Xe-136 + AU-197

<u>Nuclide</u>	<u>Spin</u>	<u>Yield(mb)</u>
Ba-133	1/2+	~0
Ba-133m	11/2-	17.7
Cs-134	4+	~20
Cs-134m	8-	~20
Pm-148	1-	1.8
Pm-148m	6-?	3.3
Re-182	2+	40
Re-182m	7+	7.9
Os-183	9/2+	~18
Os-183m	1/2-	~6
Re-184	3-	~0
Re-184m	8+	10.4
Ir-186	6-	~18
Ir-186m	2-	~8
Ir-190	4+	6
Ir-190m2	11-	21
Tl-194	2-?	~0
Tl-194m	7+?	3

the foil. These energies are substantially less than the maximum energies used in the experiments being reported here, but they are included within the range explored here. They report that one Gaussian curve can be used to describe the distribution of cross sections for Au isotopes in any one experiment. The width of the curve used to fit the results from the 270-MeV Ar-40 + Au-197 reaction lies between the two component widths calculated here for the similar reaction. The graphical depiction of cross sections from carbon- and neon-induced reactions in the above reference suggests that there may indeed be two distributions of Au isotopes present. Unfortunately, the existence of the 2.27-day Au-198 high-spin isomer was not then known, and its cross section was not measured. It is here proposed that the earlier observations apply mostly to the products of the quasi-elastic transfer mechanism and that evidence for the deep-inelastic mechanism is mostly buried by its more abundant associate.

C. The "Gold Finger"

The initially unexplained group of nuclidic yields observed in heavy-ion reactions with a thick uranium target⁷ and called the "gold finger" can now be interpreted. These yields appeared in the neighborhood of forty mass units below the uranium target and formed an isolated group of yields.

Examining the distribution of yields from the heavy-ion bombardment of thick gold targets reveals that during the course of the deep-inelastic reaction a sufficient number of nucleons can be transferred or

evaporated out of the target gold nucleus so that the remaining entity can be more than fifty mass units lighter than the original mass of 197. The X-ray spectra similarly show the existence of products so far removed from the target.

It was found that some nuclides appeared in diminished yields below what was expected from the heavy-ion bombardment of gold. These nuclides were above the closed proton shell at $Z = 82$, and it was postulated that the loss in yield occurred because of fission of a precursor nucleus that did not manage to lose enough excess energy by evaporation and gamma-ray emission.

Combining these two ingredients, large displacements below the target and fission above the region of shell closure, provides the explanation for the so-called gold finger. One important point that has not been explained is the ability of the precursor nucleus to evaporate a large number of nucleons without undergoing fission even though excitation is high and fission barriers are low. This inconsistency calls into question the current understanding of nuclear fission.

The enhanced stability that sets in around the double shell closure of $Z = 82$ and $N = 126$ points out that shell effects can play an important role in affecting the yields of heavy-ion reactions.

D. Fragmentation Theory

A theoretical model has been recently developed⁷¹ and applied to fitting the mass-yield distribution obtained in the bombardment of a thick U-238 target with Kr-84. Among the features of the model are

relatively rapid charge and mass transfer to achieve the minimum potential energy, slower motion along the fission axis joining the centers of the two fragments, and a Boltzmann distribution of states governed by the excitation energy. The initial rapid charge equilibrium should produce nuclides centered at $Z = 94$ and $Z = 34$. The paper proposes that separation occurs after the transfer of sufficient nucleons between the target and projectile to mimic asymmetric fission of the fused nuclear system and with the distribution reflecting the nuclear potential energy surface. A large excess of yield in the vicinity of $A = 184$ is believed to undergo asymmetric sequential fission, and this should also apply to the neighborhoods of $A = 202$ and $A = 208$. Virtually no products appear corresponding to the symmetric division of the total mass, and a gold finger distribution is obtained.

Such a model is not supported by the experimental results from the heavy-ion bombardment of gold. The exchange of nucleons between the target and projectile seems to be limited by the kinetics of the process; higher energy bombardments enable longer contact time between the two nuclei and a greater amount of mass diffusion. Also, the transition between side peaking of the angular distribution to forward peaking as the energy is increased supports the kinetic, rather than thermodynamic, picture of the deep-inelastic reaction mechanism. The products resulting from the deep-inelastic mechanism are primarily to be found in the neighborhood of the target and projectile, and evidence is lacking for a high probability of extensive exchange of nuclear matter. The nuclear diffusion that does occur appears to be smoothly continuous and is

capable of achieving mass symmetry. The local fluctuations in the nuclear potential energy surface are not to be observed in the product yields. Sequential fission occurs for products beyond the lead shell closure, and none can be deduced for the regions reported in the above paper. The gold finger distribution is explained as a logical consequence of the deep-inelastic mechanism.

Of course, the theoretical calculation was performed for the system $\text{Kr-84} + \text{U-238}$, and the experimental results here refer to various heavy ions, including krypton, and a gold target. It would certainly prove interesting if the extensive calculations could be carried out for a gold system to ascertain whether any of the discrepancies can be explained and resolved. It is also hoped that the more realistic calculations that are being performed will serve to improve the situation.

E. A Proposed Reaction Scenario

The following scenario is proposed to describe the collision of a heavy ion with a gold nucleus at an energy above the Coulomb barrier.

The first possible case occurs for the largest impact parameters and highest angular momentum l-waves. The overlap of nuclear matter must be very slight or non-existent because the two passing nuclei maintain velocities similar to those possessed prior to the close interaction. The overlap of the nuclear potentials creates a pathway for the exchange of nucleons, but only very few cross because the junction cannot be very large and the interaction time is quite short. The product yields lie very close to the target and projectile origins because of

the meager nucleon exchange and small amount of particle evaporation. The internal excitation of the nuclei cannot be very great because few nucleons are exchanged, the time and area for collisions to occur are both small and the two fragment kinetic energies are observed to be nearly equal to the initial projectile kinetic energy.¹⁸ The grazing angle is the most likely angle of emission for the reaction products since they follow a Coulomb trajectory. The quasi-elastic reaction mechanism fits this description.

Most collisions involve greater overlap of the attractive nuclear potentials. The target and projectile nuclei hang together for such a long time and so strongly that no part of either nucleus can ignore the interaction. Processes that are rate limited can begin to take place and may reach completion. Energy can be transferred among the various modes that are coupled together. Many nucleons can be passed between the two nuclei in contact, and these particles effectively convert kinetic energy to internal excitations.

When the attractive potential is adequately large relative to the kinetic energy remaining after some initial kinetic energy is damped, the two colliding nuclei can fuse together to form one system. If the fused system stays together long enough for statistical equilibrium to be achieved, the compound nucleus mechanism is operative; if the fused system falls apart before arriving at equilibrium, one has a case of fusion-fission. These mechanisms were observed for lighter projectile reactions with a heavy target, such as gold.

Greater kinetic energy must be given to higher-Z projectiles in order to surmount the increased Coulomb barrier. In addition, the greater mass involved in the reaction and the larger maximum impact parameter both increase the average angular momentum barrier. The attractive nuclear potential is smaller due to the increased Coulomb repulsion effects. As the projectile mass and atomic number increase, it becomes less likely that the attractive potential will exceed the damped energy. The two nuclei may rotate about each other, and as they do, nucleons are exchanged, and the neck connecting them has time to grow and to increase their mutual attraction. Out of this increasing neck growth may be the exponential tailing observed in the direction of symmetry within the mass-yield distribution. Greater projectile kinetic energy increases the initial overlap of the nuclei and leads to greater possible exchange of nucleons. But it is less likely, in light of the larger excitation, the system will be able to hold together. The two fragments usually come apart before mass transfer can be completed.

The deep-inelastic mechanism has the property that the exit-channel kinetic energy is approximately equal to the Coulomb repulsion energy, and excess initial energy must temporarily reside within the nucleus. Figure 46 depicts the fate of this excitation energy. For a thin target and mono-energetic projectile beam, the excitation energy is divided into a portion tied up in angular momentum, represented by the yrast line, and the remainder found in internal excitations. At first, the fastest means of de-excitation is used. Particles are evaporated, but the angular momentum barrier inhibits the particles from carrying off more than the

intrinsic $1/2\hbar$ they possess. Each particle evaporated reduces the nuclear excitation by its binding energy and kinetic energy, and 10 MeV might be a typical value for this sum. The protons and other charged particles that are evaporated must overcome a Coulomb barrier in order to escape, and, as a nucleus cools down, it becomes less likely that the charged particles can acquire enough energy to escape; neutrons are emitted more often than not. As the nuclear excitation energy comes within about 10 MeV of the yrast line, the chances that one nucleon can obtain enough energy to be evaporated become quite slim, and an E1 gamma-ray transition will probably de-excite the nucleus down to the yrast level. Again, not much has been accomplished in ridding the nucleus of angular momentum because the gamma ray possesses only $1\hbar$. When the nucleus arrives at the yrast line, collective E2 gamma-ray transitions bring it down the yrast line. As was noted earlier, high-spin isomeric states can trap the yields of the deep-inelastic mechanism as it moves down the yrast line. As can be seen in figure 46, more particle evaporation should be associated with less gamma-ray emission. This would account for the virtually complete selection of the high-spin isomeric states by gold isotopes produced in the deep-inelastic transfer reactions. One would expect less isomer selection as the products become further removed from the target or projectile, and this is observed.

Any nuclei made above the lead nucleon shell closure stand a good chance of undergoing the sequential fission that is observed.

The analysis of thick-target experiments, such as the ones covered in this report, is similar to that just given except that the excitation energy ranges from the initial maximum to zero.

F. Concerning the Synthesis of Super-Heavy Elements

The use of heavy-ion nuclear reactions in the attempt to synthesize super-heavy elements has been earlier discussed. The results of the present experiments should now be examined to determine what they might suggest concerning the chances for elemental synthesis.

The three types of nuclear reaction mechanisms mentioned in this regard were compound-nucleus formation (with subsequent evaporation of particles), fusion-fission reaction (where one surviving fragment would lie within the Island of Stability) and a transfer mechanism (providing an additional number of nucleons to a heavy target). Two kinds of transfer reactions, quasi-elastic and deep-inelastic, can be separately considered.

Perhaps the greatest drawback of the compound-nucleus approach is the difficulty of obtaining the high neutron-to-proton ratio characteristic of the line of beta stability within the Island of Stability.⁷²

For the doubly-magic nucleus $^{298}_{114}184$, this ratio is equal to 1.61,

whereas it is 1.55 for the sum of two of the best components:

$^{48}_{20}\text{Ca} + ^{248}_{96}\text{Cm}$.⁷³ Of course, the sum ratio will be made even more unfavorable by neutron evaporation from the excited compound nucleus. The emission of charged particles, which would work to aid the stability of the product nucleus, is inhibited by the high Coulomb barrier.

An examination of the yields obtained in the heavy-ion reactions with a gold target shows that there is little conclusive evidence for formation in substantial yield of a compound nucleus or fused nuclear system resulting from the collision of the heavier projectiles (^{84}Kr ,

^{86}Kr , ^{136}Xe with gold nuclei. Such a finding argues against the usefulness of ^{76}Ge as a projectile for a compound-nucleus type reaction to produce super-heavy elements.⁷⁴

The use of heavier ions for the compound nucleus reaction, along with a correspondingly lighter target nucleus, gives a higher Coulomb barrier to surmount than the barrier for a lighter projectile and heavier target yielding the same compound nucleus, the additional kinetic energy that must be given a heavier projectile to overcome the higher Coulomb barrier increases the probability that any compound nucleus that might form will fission due to its excitation energy. So the use of very heavy ion projectiles to synthesize new elements via the compound nucleus mechanism would seem to show little promise when compared with the use of lighter projectiles, and the present experimental results certainly cast doubt on the likelihood of compound nucleus reactions yielding products far beyond the Island of Stability. One will probably have to use a different technique to reach the next predicted region of enhanced nuclear stability around $Z = 164$ ⁷² and the onset of the atomic electron binding catastrophe beyond $Z = 172$.⁷⁵

As mentioned above, the distribution of reaction products gave a hint as to the occurrence of the fusion-fission mechanism when krypton or xenon ions were used as projectiles. One may speculate upon what will happen when uranium projectiles will become available for bombarding heavy targets.⁷⁶ It has been thought that super-heavy elements might survive the energetic fusion of two heavy nuclei. These experiments lend no support to such hopes and, rather, lead to the prediction that each

nucleus in the reaction (e.g., $^{238}\text{U} + ^{238}\text{U}$) will basically maintain its own identity and that fissile products stand a very good chance of undergoing sequential fission. One should then not expect the fusion-fission reaction mechanism to be an effective pathway to the Island of Stability and beyond.

The quasi-elastic transfer mechanism possesses the distinct advantage of converting little of the initial kinetic energy into internal excitation. This point is highly important because although nuclides contained within the region of enhanced stability are less prone to fission than neighboring nuclides, these nuclides are still expected to possess barriers against fission of ten MeV or less.⁷⁷ A large amount of internal excitation would most probably lead to fission and loss of virtually all of the desired products. The quasi-elastic mechanism suffers less from this drawback, as can be seen in the survival of the majority of the target "rabbit ear" in heavy-ion reactions with a uranium target and the few nucleons lost by evaporation.

The distribution of products resulting from the quasi-elastic transfer of nucleons has a very narrow width. Assuming this distribution is Gaussian in shape and centered at the target mass, one can calculate the relative yield for the transfer of, perhaps, thirty nucleons. Setting the standard deviation of the distribution to 1.50, one calculates that yield should be 170 orders of magnitude below the maximum of the distribution! This calculation used very favorable parameters, and the true result can only be worse. And the calculation has not included the possible loss of product by fission.

The deep-inelastic transfer mechanism does involve the conversion of a large amount of initial projectile kinetic energy into internal excitation; this certainly presents a disadvantage in the attempt to synthesize super-heavy elements. However, the substantial contact between the target and projectile nuclei permits considerable transfer of nucleons between the two. When either xenon or krypton ions were used, a majority of the total reaction cross section went into the deep-inelastic transfer channel. Comparing the distribution of yields from the two reactions, one finds that the tendency to transfer nucleons from the target nucleus to the projectile is reduced in going from $^{84,86}\text{Kr}$ to ^{136}Xe . The Q-values of the reactions yielding products at symmetry are around 55 MeV for the krypton reactions, but only 7.3 MeV for the $^{136}\text{Xe} + ^{197}\text{Au}$ case (Table 19); thus the reaction energetics favor moving nucleons from the target to the projectile less strongly when the xenon reaction occurs. Extrapolating these findings to the proposed reaction $^{238}\text{U} + ^{238}\text{U}$, one immediately sees that no driving force originating in the energetics of the reaction can exist to move nucleons from one nucleus to the other. It might be hoped that with the dispersion of products about the maximum there would be yields of the super-heavy elements. Both the evaporation of particles and prompt fission encouraged by the large degree of internal excitation serve to deplete any production of super-heavy elements, but the techniques used in the search for these nuclides are sensitive to the presence of less than 100 fissioning atoms.

REACTIONS AND MASS DEFECTS (MeV)

Q-VALUE

XBL 776-9050

The reaction $^{86}\text{Kr} + ^{197}\text{Au}$ was performed at two different maximum projectile energies, and at the higher energy, more nucleons were transferred, and the distribution was wider for the deep-inelastic components. This can be understood in terms of higher energy leading to a greater overlap of the nuclear potentials and a longer contact time. The longer the target and projectile nuclei are together, the greater the opportunity to exchange nuclear matter. However, the larger projectile energy also causes a greater amount of nuclear excitation in the products because the final kinetic energies approximately equal the Coulomb repulsion energy irrespective of the incoming energy. The greater nuclear excitation will enhance the chances of sequential fission, and what is gained by the greater probability of many-nucleon transfer as the projectile energy increases may be lost through the fission exit channel.

In these thick target experiments, the maximum projectile energy was 8.4 MeV per atomic mass unit (except for the Ne-20 experiments), and the reactions covered the entire energy range from the maximum to below the Coulomb barrier. It cannot be ruled out that the fusion-fission or compound nucleus mechanism would become visible at higher Kr or Xe projectile energies where, perhaps, the target and projectile would have sufficient time to attain a shape more stable for the fused composite system. And the brute force approach might bring about adequate overlap of the nuclear potentials to allow fusion. Only future heavy-ion accelerator development can clear this up.

V. CONCLUSIONS

A. Summary

Radiochemical techniques have been used to measure the yields of nuclides produced by the reactions of several heavy ions (Ne-20, Ar-40, Kr-84, Kr-86, and Xe-136) with the gold nucleus. Based on the assumption of Gaussian distributions for the yields as functions of reaction mechanism, atomic number and mass number, mass-yield distributions and integrated mechanism yields were calculated.

The following points were observed:

- 1) The fusion-fission reaction mechanism, common when lighter ions were used, is replaced by the deep-inelastic transfer mechanism when heavier projectiles were utilized.
- 2) A component corresponding to symmetric mass division was observed in the mass-yield distribution from the reaction $620\text{-MeV Kr-86} + \text{Au-197}$, and this is most likely due to the fusion-fission mechanism.
- 3) The deep-inelastic reaction mechanism is characterized by exponential tailing in the mass-yield distribution toward the direction of symmetric division of mass, greater mass transfer at higher projectile energies and preferential mass transfer from the heavier target to the lighter projectile.
- 4) Sequential fission depletes yields of nuclides above the closure of nucleon shells in the neighborhood of lead.

- 5) The cause of the gold finger is a combination of sequential fission, mass transfer and nucleon evaporation.
- 6) The yield of gold nuclides indicates the presence of two distributions, quasi-elastic and deep-inelastic components, and angular momentum effects are expressed in isomer fractionation.
- 7) An unexplained relationship exists for the integrated quasi-elastic yield of gold isotopes as a function of projectile mass.

An extensive series of computer analysis programs was used to effectively and expeditiously obtain the desired results.

B. Suggestions for Further Experiments

The ability to study nuclear reactions induced by ^{197}Au is close at hand,⁷⁶ and this suggests attempting the worthwhile experiment $\text{Au-}^{197} + \text{Au }^{197}$. The symmetry of target and projectile eliminates any doubt about the origins of a product nuclide. It is expected that deep-inelastic and quasi-elastic transfer reactions will dominate the exit channels, but it might be found that sequential fission following the initial interaction will play an increasingly large role. Products of such sequential fission, having a mass in the neighborhood of $A = 100$, should be seen unobscured by yields from other reaction mechanisms, and their study will be facilitated. The symmetry of target and projectile will probably prevent the observation of any fusion-fission component because the

symmetric fission will yield nuclides also made by the deep-inelastic mechanism; the only hope is that the fusion-fission component is wide and large enough to appear beyond the deep-inelastic distribution. An additional advantage of using identical target and projectile nuclei is the absence of a potential energy driving force tending to move nucleons from one nucleus to the other; one has isolated the random portion of the reaction process from the driven part. A study of the dispersion of yields as a function of projectile energy is highly desirable.

The reaction $\text{Kr-86} + \text{Au-197}$ was studied in two sets of experiments with differing maximum beam energies. The results indicate that a wider distribution of products from the deep-inelastic is obtained when the beam energy is increased. To extend these findings further, additional experiments should be performed at lower energies. Any fusion-fission component buried beneath the wide distribution of the deep-inelastic transfer mechanism becomes more visible. The exponential tailing on the Gaussian curve used to model the deep-inelastic product distribution could be better investigated with a narrow distribution. At the other end of the energy spectrum, higher energy heavy-ion beams will help investigate the disappearance of collective nuclear effects during the collision and the transition to the direct reactions observed at very high energies.

Very short bombardments (~ 10 seconds) and short counting periods will permit measurement of the yields of short-lived Au isomers (Au-193m , -195m , -197m) to further verify the separation into quasi-elastic and deep inelastic components. An automated system can utilize a rabbit

carrying the gold target foil directly from the irradiation position to the face of a Ge(Li) gamma-ray detector.

Further chemical separation experiments should be carried out to elucidate the distribution of products with greater accuracy, precision and sensitivity. The fate of angular momentum in the de-excitation of nuclei and product yield as a function of angular momentum should be further studied by examining isomer ratios more closely for additional nuclidic pairs. The high-mass portion of the nuclidic yield distribution can be further explored by preparation of very thin chemically-separated samples for alpha spectrometry. Preliminary results obtained from an Ar-40 experiment showed the presence of substantial amounts of neutron-deficient, alpha-emitting polonium nuclides. The short half lives of many nuclides above the closed shells of $Z = 82$ and $N = 126$ would certainly complicate any attempted analysis.

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FIGURE CAPTIONS

- Figure 1. Results of 605-MeV Kr-84 + U-238 radiochemical experiments:
a) individual isotopic yields, b) contour plot of calculated independent yields, c) integrated mass yields and component factorization.
- Figure 2. SuperHILAC Kr-86 beam energy calibration; by intensity versus energy.
- Figure 3. Outline of target foil 53 AU before and after trimming; exposed area indicates location of activity.
- Figure 4. Chemical flow diagram for experiment 64 AU to produce Au, TL, HG, and LA samples.
- Figure 5. X-Ray spectrum of sample AU 64 AU.
- Figure 6. X-ray spectrum of sample TL 64 AU.
- Figure 7. X-ray spectrum of sample HG 64 AU.
- Figure 8. X-ray spectrum of sample LA 64 AU
- Figure 9. Rare earth decay properties from Chart of the Nuclides
- Figure 10a-b. Glass flask used for chemical processing of gold target.
- Figure 11. Chemical scheme for group separation.
- Figure 12. Gamma-ray spectrum of gold foil from 1140-MeV Xe-136 + Au-197 experiments; energy frange is 75 keV to 2000 keV.

Figure 13. Flow diagram of computer programs used for data analysis scheme.

Figure 14a-b. SAMPO fit for portion of gamma-ray spectrum

Figure 15. TAU 2 display: linear fit.

Figure 16. TAU 2 display: linear fit for half life of 42 minutes.

Figure 17. TAU 2 display: sum fit for half lives of 5 hours and 32 minutes.

Figure 18. TAU 2 display: growth and decay.

Figure 19. TAU 2 display: linear fit plus hand fitting later identified as TH-228 (583.2 keV) background.

Figure 20. Gaussian distribution of calculated independent yields for the mass region A = 88-105 from the reaction 1140-MeV Xe-136 + Au-197.

Figure 21. Individual nuclidic yields: 252-MeV Ne-20 + Au-197

Figure 22. Individual nuclidic yields: 336-MeV Ar-40 + Au-197.

Figure 23. Individual nuclidic yields: 705-MeV Kr-84 + Au-197.

Figure 24. Individual nuclidic yields: 730-MeV Kr-86 + Au-197.

Figure 25. Individual nuclidic yields: 620-MeV Kr-86 + Au-197.

Figure 26. Individual nuclidic yields: 1140-MeV Xe-136 + Au-197.

Figure 27. Mass-yield data and total fit: 252-MeV Ne-20 + Au-197.

Figure 28. Component and total fitted curves: 252-MeV Ne-20 + Au-197.

Figure 29. Mass-yield data and total fit: 336-MeV Ar-40 + Au-197.

Figure 30. Component and total fitted curves: 336-MeV Ar-40 + Au-197.

Figure 31. Mass-yield data and total fit: 705-MeV Kr-84 + Au-197.

Figure 32. Component and total fitted curves: 705-MeV Kr-84 + Au-197.

Figure 33. Mass-yield data and total fit: 730-MeV Kr-86 + Au-197.

Figure 34. Component and total fitted curves: 730-MeV Kr-86 + Au-197.

Figure 35. Mass-yield data and total fit: 620-MeV Kr-86 + Au-197.

Figure 36. Component and total fitted curves: 620-MeV Kr-86 + Au-197.

Figure 37. Mass-yield data and total fit: 1140-MeV Xe-136 + Au-197.

Figure 38. Component and total fitted curves: 1140-MeV Xe-136 + Au-197.

Figure 39. X-ray spectrum of gold foil from Kr-84 + Au-197 experiment of a heavy-ion reaction and subsequent de-excitation.

Figure 40. Yield of gold nuclides versus mass number: 336-MeV Ar-40 + Au-197.

Figure 41. Yield of gold nuclides versus mass number: 252-MeV Ne-20 + Au-197.

Figure 42. Yield of gold nuclides versus mass number: 730-MeV Kr-86 + Au-197.

Figure 43. Yield of gold nuclides versus mass number: 620-MeV Kr-86 + Au-197.

Figure 44. Yield of gold nuclides versus mass number: 1140-MeV
Xe-136 + Au-197.

Figure 45. Gold quasi-elastic gaussian area versus projectile $A^{2/3}$.

Figure 46. Pictorial representation of a heavy-ion nuclear reaction and
subsequent de-excitation.

Fig. 1.

Fig. 2.

Fig. 3.

CHEMISTRY SCHEME FOR EXPERIMENT 64AU

Fig. 4.

XBL 776-9052

X-RAY SPECTRUM

FILE= X

XBL 776-9188

Fig. 5.

Fig. 6.

X-RAY SPECTRUM

FILE = X

Fig. 7.

XBL 776-9189

Fig. 8.

CBB 775-5297

Fig. 9.

CBB 754-2562

Fig. 10a.

CBB 754-2558

Fig. 10b.

CHEMICAL SCHEME FOR GROUP SEPARATION

XBL 776-9053

Fig. 11.

Fig. 12.

DATA ANALYSIS PROGRAMS

XBL 776-9051

Fig. 13.

3.263E+03

COUNTS /
CHANNEL

RESOLVED
PEAKS

LOG SCALE

1.955E+03

1.79

DIFFERENCE

/ SIGMA

-1.94

SPECTRUM

6M A X

XBL 772-7666

Fig. 14a.

3.169E+03

COUNTS /

CHANNEL

RESOLVED

PEAKS

LOG SCALE

1.985E+03

2.06

DIFFERENCE

/ SIGMA

-1.55

SPECTRUM 6M A X

XBL 772-7667

Fig. 14b.

AU64 X 612.4KEV 612.4 SH AU-192 .210

X BK	(11)	611.3	LA	EU-148	54.000	19.3	0	(111)	612.4	SH	IA-192	74.000	9.2	IP	0	
X SUM	(12)	611.3	LA	PA-148H	41.000	9.6	0	(112)	612.2	SH	AU-201	.000	1.2	PT	0	
X BACKSC.	(13)	611.4	LA	SA-227	.020	1.3	0	(113)	611.4	LA	GD-159	.013	1.3	0	0	
X GROWTH	(4)	611.5	PT	180	.003	0.6	0	(14)	611.4	LA	EU-159	.013	1.3	0	0	
X PIT	(5)	611.6	LA	CE-133	.225	1.9	PA	0	(15)	612.6	PD	IA-104	.179	2.5	SH	10
X ONLY	(6)	611.0	SH	N-197	.004	5.1	DE	0	(16)	612.7	OT	AS-70	.063	31.0	DE	0
X DOUBLE	(7)	612.0	LA	Zn-64	.608	9.0	0	(17)	612.0	LA	PD-135	.017	3.7	NO	0	
X HALVE	(8)	612.1	LA	SH-93	.006	2.0	0	(18)	614.0	I	I-132H	.050	2.4	0	0	
X RESV	(9)	612.3	LA	PA-150	.113	1.0	0	(19)	614.0	SH	TA-104	.007	35.0	0	0	
X UP	(10)	612.4	SH	AU-192	.210	6.7	MG	100000	(20)	614.0	SH	TC-104	.013	.0	0	0
X DOWN																
X SKIP

XBL 776-9888

Fig. 15.

AU64 X 597.5KEV 597.9 SM AU-190 .029

X OK	(11) 595.9 DI AS- 74	17.700 59.2	0	(111) 597.9 SM AU-190	.029 12.4 MC	3200001
X SUM	(2) 596.0 U ZN- 71M	.163 27.3	0	(121) 598.2 LA SM-193	1.933 -0 PM	0
X BACKGR	(3) 596.1 U ZN- 71M	.163 27.9	0	(131) 598.7 LA TB-194	.384 -0	0
X GROUTN	(4) 596.6 U CS-123	.005 65.5a	0	(141) 598.7 I I -121	.000 1.5 HE	0
X FIT	(5) 596.6 U ZN- 67	.306 24.0	0	(151) 598.7 I I -121	.000 1.5	0
X ONLY	(6) 596.6 SM TL-196	.225 1.5 TL PB	0	(161) 599.0 LA YB-166	0.356 6.0u LU	0
X DOUBLE	(7) 596.9 LA SM-193	1.933 -0 PM	0	(171) 599.2 LA YB-163	.000 2.4u	0
X HALVE	(8) 596.9 LA BA-120	.094 16.0u	0	(181) 599.3 LA TB-222	.019 1.7u	0
X RESET	(9) 597.4 PB AP-200M	.005 12.5 U	0	(191) 599.5 LA CU-104	19.190 2.3 SM	0
X UP	(10) 597.7 LA CE-131A	.097 1.4	0	(201) 599.6 LA PM-140M	41.000 12.4	0
X DOWN						
X SKIP

XBL 776-8890

Fig. 16.

AU64 X 604.4KEV 604.3 SH AU-192 .210
604.8 I BR-84 .022

N BR	(11)	605.2	DI	TE-115A	.005	1.0	I	0	(111)	604.8	I	BR-84	.022	1.7	SE	5105552	
N SWP	(12)	605.2	DI	TE-115B	.005	5.0	I	0	(112)	604.9	LA	LA-134	.005	5.1	CE	0	
N BACKSC	(13)	605.2	PD	AD-79	.014	.7	SA	0	(113)	604.9	LA	CE-134	3.000	100.0	PA	0	
N GROWTH	(14)	605.6	SH	AS-102	.009	1.7	CD	AS	0	(114)	605.1	LA	AM-238	.040	7.0	CH	0
N FIT	(15)	602.6	I	I-130	.017	.4			0	(115)	605.2	I	I-110	.010	95.0	I	0
N DMIT	(16)	602.0	DI	SO-127	3.000	4.4	CM	SH	0	(116)	605.2	I	I-110H	.006	10.0		0
N DOUBLE	(17)	604.2	LA	SA-74	.004	2.9			0	(117)	605.3	SH	IN-190	12.100	37.0	IN	0
N HALVE	(18)	604.3	SH	AU-192	.210	1.6	WG	1298254	0	(118)	605.3	SH	DE-190H	.117	19.1		0
N RESET	(19)	604.4	SH	IN-192	74.000	0.1	SH		0	(119)	605.4	LA	SO-124	12.400	1.4	SB	0
N UP	(10)	600.6	U	CS-134	791.000	90.0	CS		0	(120)	605.5	LA	TO-151	.750	1.0	OV	0
N DOWN																	
N SKIP

XBL 776-8887

Fig. 17.

X 316.1KEV

316.5 SH AU-192

. 2 1 0

0000040A5H=0000000A-2=; ; 219

[illegible] **XBL 776-8891**

Fig. 18.

AU64 X 582.7KEV 582.6 SH AU-192 .210
42.947 K FIT K F

X ON	(11) 582.1 LA 88-1000	.004	54.0	0	(11) 582.1 SH 81-212	.042	21.0	PH	0
X SUM	(12) 581.4 LA 84-222	1.010	6.3	0	(12) 582.2 LA 78-220	697.196	20.7	SC U	0
X BACKSC.	(13) 582.0 LA 88-150	.025	7.0	TH	(13) 582.2 LA 78-164N	.004	9		0
X BACKTH	(14) 582.0 SH 74-100	.007	1.0	0	(14) 582.3 01 58-127	.000	2.4		0
X FIT	(15) 582.0 PH 10-110H	.004	9.1	0	(15) 582.3 LA 85-250H	1.438	2.7		0
X ONIT	(16) 582.0 LA 82-154	959.999	.0	0	(16) 582.4 LA 10-168	.005	2.2	HP	0
X DOUBLE	(17) 582.1 SH 76- 95H	61.000	32.5	DU	(17) 582.4 1 AT-207	.075	1.7	GM PH	0
X HALVE	(18) 582.5 01 68- 76	.000	1.0	DS	(18) 582.9 LA 18-163	.019	7.3		0
X RESET	(19) 582.6 SH 60-192	.210	9.1	MS	1270782 (19) 584.0 SH 18-104H	.073	2.0		0
X UP	(10) 582.9 LA 58-120	.371	1.0	SH	(20) 584.0 LA 60-150	959.999	60.0		0
X DOWN									
X SKIP

XBL 776-8889

Fig. 19.

XBL775-1155

Fig. 20.

Fig. 21.

XBL 776-8986

XBL 776-8983

Fig. 22.

XBL 776-8982

Fig. 23.

XBL 776-8981

Fig. 24.

XBL 776-8980

Fig. 25.

XBL 776-8984

Fig. 26.

Fig. 27.

XBL 776-8991

XBL 776-8990

Fig. 28.

XBL 776-8985

Fig. 29.

XBL 776-8988

Fig. 30.

XBL 776-8992

Fig. 31.

XBL 776-8987

Fig. 32.

XBL 776-8996

Fig. 33.

XBL 776-8989

Fig. 34.

XBL 776-8995

Fig. 35.

XBL 776-8994

Fig. 36.

XBL 776-8997

Fig. 37.

XBL 776-8993

Fig. 38.

Fig. 39.

XBL 766-8255

XBL 776-9186

Fig. 40.

XBL 776 - 1156

Fig. 41.

XBL776-1159

Fig. 42.

XBL776-1157

Fig. 43.

Fig. 44.

XBL 776-1158

XBL 776-1160

Fig. 45.

XBL776-1154

Fig. 46.