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TARGET RADIOACTIVITY CONTENT AT AGS

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Introduction

The following is a characterization of radioactivity in platinum, copper, gold and nickel targets. These targets are used or proposed for use at the AGS.

In targets that intercept high intensity proton beam, the radioactivity per unit mass is nine orders of magnitude greater than other beam-line materials. The nuclide type in targets, after several months of decay, is very much different from other AGS materials. Additionally, the retention of this radioactivity within the target is influenced by the high heat generated from the interaction with the proton beam. This document attempts to record the expected radioactivity in AGS targets. Additionally, observations are made with regard to the dispersability of radioactive materials within the targets. A recommendation to contain high intensity targets is also made.

Primary Target Environment

The Alternating Gradient Synchrotron has been in operation for 32 years providing protons for the high-energy physics program, and in addition for the past nine years providing heavy ions for the nuclear physics program. The proton beam intensity of the AGS has increased by about a factor of six since the start-up of the AGS Booster in 1993. These higher intensity proton beams are being delivered to targets made of platinum and copper. Future plans indicate nickel and gold targets may be used.

At this time, the total accelerated proton beam (H^+) output from AGS is about $6x10^{13}$ protons at about 24 GeV every 2 to 3 seconds for AGS experimental areas.

Since the AGS can accelerate all ion species, a generic measure of other accelerated ion species is stated in terms of nucleons. For example, Au ions have 197 nucleons. For ion species other than H^+, AGS accelerates about 10^{11} nucleons every 2 to 3 seconds. The individual experimental beam lines see relatively low intensities of heavy ions, and the properties of the heavy ion beam are studied directly. The heavy-ion research program does not result in intensely radioactive targets or stops at this time.

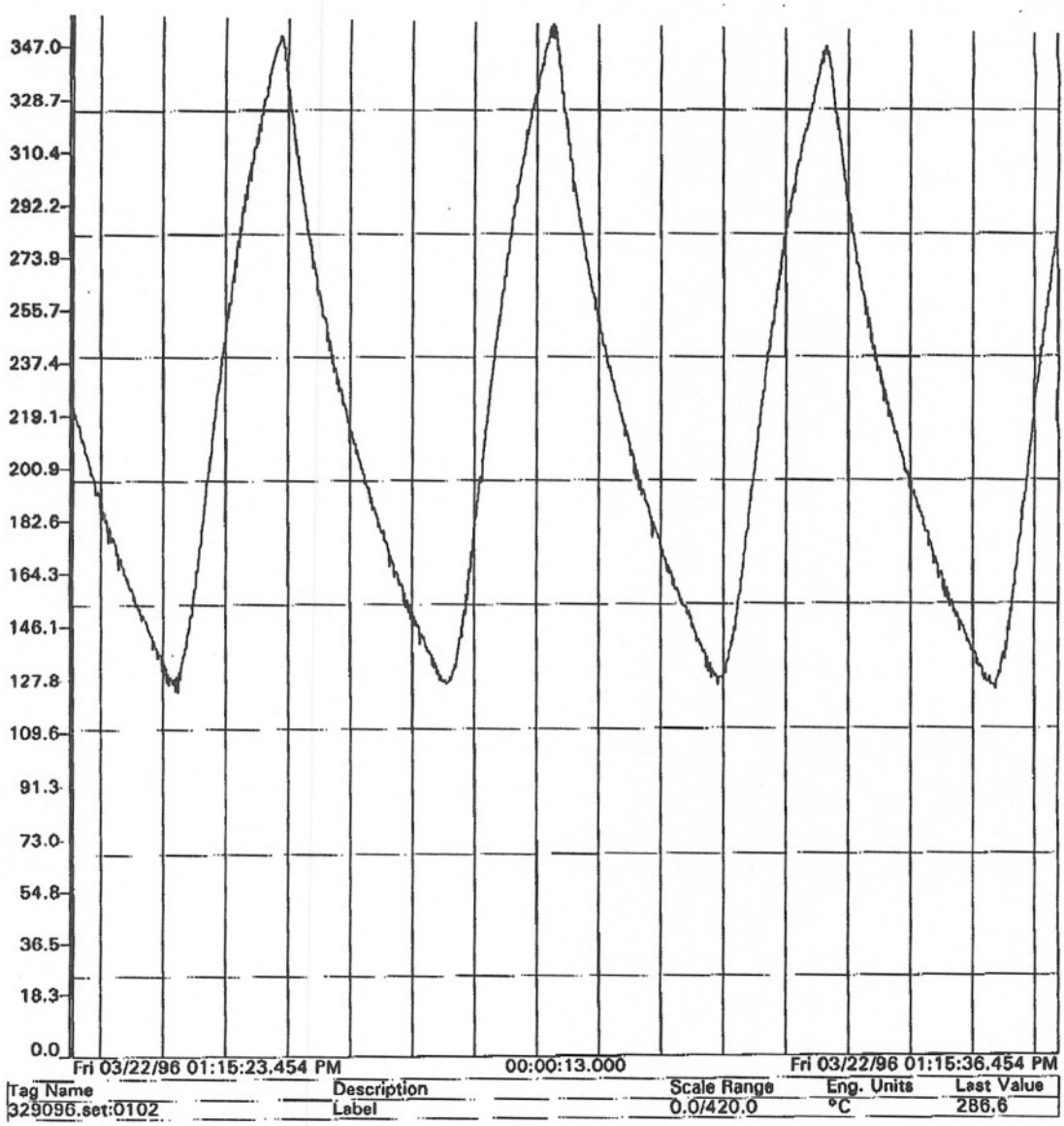
The energy of an accelerated proton may be as high as 30 GeV, but generally is 24 GeV. Most accelerated protons end up at the targets inside heavily shielded target halls with locked and interlocked gates. The target halls typically have 12-foot thick high-density-concrete walls. During transport through many hundreds of yards of transport lines, and many hundreds of yards of accelerators, a small percentage of the proton beam is lost. Measurements made over the last few years at AGS indicate the activity per unit mass of beam line materials, except for targets and beam dumps, ranges from 1 to 5 nCi/g due to this beam loss. After several months of decay, the predominant measured nuclide in beam-line materials tends to be 5.271 year ^{60}Co. The accelerators are typically shielded with 20-foot roofs and 60-foot sides of earth berm. The lost beam normally interacts with in-line beam-line components such as magnets, vacuum pipes and cables. Scattered

secondary particles are also relatively high energy and they interact in the concrete and earth shielding.

Uncollided accelerated protons and forward scattered particles that end in the target halls are stopped in iron beam dumps that are up to 50-yards long and come after the targets. The target halls, or target caves as they are sometimes called, tend to be the locations where the highest level of residual radioactivity is measured. Target caves contain items similar to items found in transport lines. They also contain the small targets that are usually about one hundred grams of mass. However, the proposed rotating nickel target for the V Target Cave will have an effective mass of 1300 grams in the beam. About one-half to two-thirds of the beam interacts once in the target. Following the target, the uncollided beam and forward scattered particles proceed either to the next target down stream or they go directly to an iron dump. Secondary particles emitted from the proton interactions in the target emanate in all directions and irradiate nearby magnets and shield walls.

The high level of long-lived residual radioactivity in the target is due to long-term bombardment during the operation of the high-intensity proton program which in recent years has run for about 20 weeks per year. Many targets in the complex are re-used over several running periods.

Heat and stress are generated in primary targets; that is, the motion of some of the atoms in the target is increased dramatically during the spill of a single pulse on a target. Normal operating temperatures in the target rise to as much as 600 °C although some targets run cooler at 400 °C. Stress rises to tens of thousands of psi. This heat or stress is quasi-static. That is, heat and stress will build-up over the time it takes for the increased motion of the target atoms to transfer that motion to atoms in the base that supports the target. This motion is transferred via collisions to the motion of the much cooler copper or beryllium base. The time involved for significant heat-motion to transfer to the base is about half a second for slow-extracted-beam (SEB) targets. The slow extracted spill itself takes one second and target atoms begin to transfer their motion to the base during the middle of the spill. The target temperature begins to rise more slowly during the remaining half second of the spill. At the end of the spill, the peak target temperature returns to a lower level. This process is repeated about 1000 times per hour and appears as a saw-tooth pattern of temperature. This quasi-static condition is pictured as follows.



It must be noted that the spill of the AGS tends toward shortening on its own if left unattended by operators, and could shorten to as much as 0.5 seconds. If this should inadvertently occur during the spill, temperature in the target would rise and approximately double.

Fast-extracted-beam (FEB) targets have a quasi-static component similar to the SEB targets; however, the FEB targets will rotate and dip through a water bath once every second at 60 rpm. Unlike the ribbon-like spill of SEB, the FEB pulse is delivered in eight consecutive bunches. Each bunch is a few nanoseconds duration and all eight bunches are delivered in about 200 milliseconds. Each bunch hits a different spot on the rotating target. Thus as long as the target moves, the temperature reaches only about 50 °C above ambient levels and stress levels rise to about 4000 psi. The target spot then rotates into

the water bath which cools it and decreases the level of stress. If all eight bunches hit the same spot because the target stops rotating, then the temperature and stress levels are added. These temperature and stress levels would then be similar to the non-rotating SEB targets. However, unlike the SEB, each nanosecond bunch creates dynamic stress, a shock wave. This is similar to the shock wave created when the nose of an aircraft begins to travel faster than the speed of sound in air.

In the FEB case, the nanosecond proton bunch strikes a large group of target atoms virtually instantaneously and the atoms begin to move faster than the speed of sound in nickel. This shock wave adds 20,000 to 30,000 psi at the shock front that dissipates quickly as the wave moves toward the edges of the target. If rotating properly, the sum of the dynamic stress and the quasi-static stress should be less than the yield strength for the target at any given point. The yield strength is reported to be about 50,000 psi for the type of nickel used at AGS. Thus, remaining below the yield strength would be possible as long as the nickel target rotates throughout all eight bunches of a spill. It is noted that fast acting interlocks have been placed on the FEB target rotating mechanism in order to forestall high temperatures and stress levels should the target stop rotating.

Activation of Targets At AGS

Stopping high-energy particles will initiate reactions in the nuclei of atoms of targets. These initial interactions produce secondary particles such as neutrons, other protons and pions. The pions behave like protons, only they are less massive and are short lived.

The nuclei of atoms struck by these high-energy particles will fragment. This fragmentation results in a range of lower mass nuclei plus many lower-energy neutrons. Tens of neutrons 'boiling-off' the compound nucleus formed by a high-energy particle and a target nucleus is not uncommon. After spallation, some fragments of the compound nucleus emit many more neutrons. After the fragments emit neutrons, quasi-stable short-lived radionuclides are formed. Thus, many spallation fragments are proton-rich and decay by positron emission (β^+) or electron capture (EC) toward a stable nuclide configuration. These two decay modes increase the neutron number in the daughter nuclide until a stable element is formed and decay stops. Most radioactive daughters produced in this fashion are short lived, minutes to days. Positron decay produces 0.511 MeV annihilation electromagnetic radiation that is easily seen via standard gamma spectroscopy. EC produces many x rays since the electron shell vacancies fill up again. This is also observed via standard photon spectroscopy.

Some of the low-energy neutrons that are 'boiled-off' from the compound nucleus or some that are emitted from spallation fragments are absorbed by the other nuclei. The absorption increases the mass of the struck nucleus and makes it unstable or radioactive. These neutron-rich nuclides decay by β^- emission which is often accompanied by high-energy photon (MeV) emission from the decay of short-lived metastable states of the daughter nuclide. A very common long-lived β^- emitter found at AGS is Co-60.

Additionally, some neutron-rich spallation fragments are formed directly from high-energy particle interactions.

The materials used in construction of AGS targets are limited in number, the most important being platinum. The V target is to be constructed out of nickel which is intended to survive the high-stress levels associated with being struck by a beam spill of a few nanoseconds duration. Actual or proposed targets for slow extracted beam where spill length is on the order of one second are copper, platinum and gold. Braze materials are used to attach the platinum targets to beryllium bases. Copper bases used with platinum targets are electro-plated to each other rather than brazed. Braze materials and base materials are not purposely targeted although they will 'see' significant secondary fluence. The radioactivity of the braze materials is not covered here; however, it will be several orders of magnitude less than the target.

At hadron particle energies higher than 20 MeV, the total inelastic interaction cross-section approaches the geometric cross-section for the nucleus. This is of the order of 800 millibarns for copper and nickel and 3000 millibarns for target masses around 200. For estimation the specific products of inelastic reactions with bombarding protons, the following formula is taken from Barbier:

$$\sigma(Z_i, A_i) = f_1(A_T) f_2(E) \frac{P e^{-P(A_T - A_i)}}{1 - 0.3 / PA_T} e^{-R\left(\left|Z_i - SA_i + TA_i^2\right|\right)^{3/2}}$$

where:

σ is the cross section for production of nuclide Z_i, A_i, millibarns,
f_1 is taken from Figure II.3 of footnote 1,
A_T is the mass number of the target atom,
f_2 is 1, taken from Figure II.4 of footnote 1,
P is 0.056, taken from Figure II.1 of footnote 1,
R is taken from Figure II.2 of footnote 1,
S is 0.486, and
T is 0.00038 and both are prescribed in Footnote 1.

From this formula, a table may be constructed for radionuclides produced in proton interactions. These tables, Tables 1 through 4, are constructed for proton beam on platinum, gold, copper and nickel targets of the size in use at AGS. Those radionuclides produced with half lives greater than 5 minutes are listed.

[1] Barbier, M., Induced Radioactivity, North Holland Publishing Company, Amsterdam, 1969.

TABLE 1

Radioactivity Content And Exposure Rate From A 5 Cm Long Platinum Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus (195.09 Equals All Stable Isotopes of Pt)	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
4.E+00	198	198	79	Au-198	6.48E+01	1.5E+01	3.12E-02	2.41E-02	1.44E-02
2.E+01	198	196	79	Au-196	9.70E+00	6.4E+01	3.51E-02	6.33E-03	2.06E-04
2.E+01	198	196	79	Au-196	1.49E+02	6.4E+01	7.07E-02	6.33E-02	5.06E-02
3.E+01	198	195	79	Au-195	4.39E+03	4.9E+01	1.17E-02	1.17E-02	1.16E-02
5.E+01	198	194	79	Au-194	3.90E+01	2.0E+02	5.81E-01	3.80E-01	1.62E-01
1.E+02	198	192	79	Au-192	3.90E+01	4.4E+02	1.26E+00	8.25E-01	3.52E-01
2.E+01	196	196	79	Au-196	9.70E+00	2.5E+02	1.39E-01	2.51E-02	8.17E-04
2.E+01	196	196	79	Au-196	1.49E+02	2.5E+02	2.81E-01	2.51E-01	2.01E-01
3.E+01	195	195	79	Au-195	4.39E+03	2.7E+02	6.61E-02	6.59E-02	6.54E-02
6.E+01	195	194	79	Au-194	3.90E+01	1.1E+03	3.27E+00	2.14E+00	9.12E-01
1.E+02	195	192	79	Au-192	5.00E+00	2.5E+03	2.28E+00	8.21E-02	1.07E-04
6.E+01	194	194	79	Au-194	3.90E+01	1.2E+03	3.39E+00	2.21E+00	9.44E-01
1.E+02	194	192	79	Au-192	5.00E+00	2.6E+03	2.35E+00	8.50E-02	1.11E-04
1.E+02	192	192	79	Au-192	5.00E+00	6.9E+01	6.31E-02	2.28E-03	2.97E-06
1.E+02	195.09	190	79	Au-190	6.33E-01	6.1E+03	6.27E+00	2.56E-11	4.28E-34
6.E+01	195.09	189	79	Au-189	6.33E-01	3.8E+03	3.88E+00	1.59E-11	2.65E-34
6.E-01	198	197	78	Pt-197	1.40E+00	2.4E+00	2.05E-03	1.44E-08	7.16E-19
6.E-01	198	197	78	Pt-197	1.99E+01	2.4E+00	2.79E-04	1.21E-04	2.28E-05
3.E+00	198	195	78	Pt-195	9.84E+01	1.3E+01	3.10E-03	2.62E-03	1.87E-03
3.E+00	196	195	78	Pt-195	9.84E+01	1.4E+01	3.50E-03	2.96E-03	2.11E-03
5.E+01	195.09	191	78	Pt-191	7.20E+01	2.9E+03	1.60E+00	1.27E+00	8.02E-01
5.E+01	195.09	191	78	Pt-191	7.20E+01	2.9E+03	1.60E+00	1.27E+00	8.02E-01
1.E+02	195.09	189	78	Pt-189	1.08E+01	6.3E+03	3.47E+00	7.45E-01	3.44E-02
1.E+02	195.09	188	78	Pt-188	2.40E+02	6.9E+03	3.80E+00	3.55E+00	3.09E+00
6.E-01	195.09	194	77	Ir-194	1.90E+01	3.4E+01	1.85E-02	7.72E-03	1.34E-03
1.E+00	195.09	193	77	Ir-193	2.86E+02	8.0E+01	1.55E-02	1.47E-02	1.31E-02
3.E+00	195.09	192	77	Ir-192	5.69E+06	7.5E-02	2.74E-04	2.74E-04	2.74E-04
3.E+00	195.09	192	77	Ir-192	1.78E+03	1.3E+02	2.23E-01	2.21E-01	2.17E-01
1.E+01	195.09	190	77	Ir-190	3.20E+00	7.9E+02	2.90E+00	1.62E-02	5.02E-07
1.E+01	195.09	190	77	Ir-190	2.95E+02	7.9E+02	9.21E-01	8.71E-01	7.78E-01
3.E+01	195.09	189	77	Ir-189	3.19E+02	1.5E+03	1.44E+00	1.37E+00	1.23E+00
4.E+01	195.09	188	77	Ir-188	4.08E+01	2.5E+03	5.48E+00	3.65E+00	1.62E+00
7.E+01	195.09	187	77	Ir-187	1.06E+01	4.0E+03	8.45E+00	1.76E+00	7.68E-02
9.E+01	195.09	186	77	Ir-186	1.58E+01	5.4E+03	5.85E+00	2.05E+00	2.50E-01
1.E+02	195.09	185	77	Ir-185	1.39E+01	5.7E+03	5.05E+00	1.53E+00	1.40E-01
7.E+01	195.09	184	77	Ir-184	3.20E+00	4.0E+03	2.65E+00	1.48E-02	4.58E-07
1.E+00	195.09	193	77	Os-193	3.12E+01	8.0E+01	4.04E-02	2.37E-02	8.18E-03
5.E-01	195.09	191	76	Os-191	3.60E+02	2.9E+01	1.84E-02	1.75E-02	1.60E-02
1.E+00	195.09	190	76	Os-190	2.00E-01	7.0E+01	2.61E-01	2.25E-37	1.68E-109
4.E+01	195.09	185	76	Os-185	2.26E+03	1.4E+03	4.55E+00	4.51E+00	4.45E+00
8.E+01	195.09	183	76	Os-183	1.34E+01	4.7E+03	6.61E+00	1.91E+00	1.60E-01
8.E+01	195.09	183	76	Os-183	9.80E+00	4.7E+03	7.80E+00	1.43E+00	4.83E-02
8.E+01	195.09	182	76	Os-182	2.10E+01	4.7E+03	1.07E+01	4.84E+00	9.95E-01
2.E-01	195.09	189	75	Re-189	2.30E+01	9.8E+00	2.66E-03	1.29E-03	3.05E-04
4.E-01	195.09	188	75	Re-188	1.70E+01	2.5E+01	4.39E-03	1.65E-03	2.34E-04
2.E+00	195.09	186	75	Re-186	8.88E+01	1.4E+02	2.33E-02	1.93E-02	1.33E-02
1.E+01	195.09	184	75	Re-184	9.12E+02	5.7E+02	2.44E+00	2.40E+00	2.31E+00
1.E+01	195.09	184	75	Re-184	4.06E+03	2.7E+02	1.62E+00	1.62E+00	1.60E+00

TABLE 1

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Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus (195.09 Equals All Stable Isotopes of Pt)	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
2.E+01	195.09	183	75	Re-183	1.68E+03	8.8E+02	7.56E-01	7.48E-01	7.33E-01
3.E+01	195.09	182	75	Re-182	3.12E+02	2.0E+03	9.82E+00	9.31E+00	8.37E+00
3.E+01	195.09	182	75	Re-182	6.48E+01	2.0E+03	4.24E+00	3.28E+00	1.97E+00
5.E+01	195.09	181	75	Re-181	1.90E+01	3.1E+03	5.62E+00	2.34E+00	4.08E-01
7.E+01	195.09	180	75	Re-180	1.99E+01	4.1E+03	2.28E+00	9.91E-01	1.87E-01
4.E+01	195.09	178	75	Re-178	2.00E-01	2.6E+03	1.28E+01	1.10E-35	8.23E-108
2.E+01	195.09	177	75	Re-177	3.00E-01	1.5E+03	7.27E+00	6.59E-24	5.42E-72
5.E-02	195.09	187	74	W-187	2.40E+01	3.2E+00	8.36E-03	4.18E-03	1.05E-03
1.E+01	195.09	181	74	W-181	3.00E+03	3.1E+02	3.25E-02	3.23E-02	3.20E-02
3.E+01	195.09	179	74	W-179	7.00E-01	1.8E+03	1.02E+00	5.06E-11	1.25E-31
3.E+01	195.09	179	74	W-179	1.00E-01	1.8E+03	9.84E-01	7.34E-73	4.08E-217
5.E+01	195.09	178	74	W-178	5.28E+02	2.7E+03	5.57E-01	5.40E-01	5.07E-01
5.E+01	195.09	176	74	W-176	2.30E+00	3.1E+03	1.52E+00	1.11E-03	5.94E-10
6.E-03	195.09	186	73	Ta-186	2.00E-01	3.3E-01	1.97E-04	1.70E-40	1.27E-112
2.E-02	195.09	185	73	Ta-185	8.00E-01	1.0E+00	8.01E-04	7.72E-13	7.18E-31
5.E-02	195.09	184	73	Ta-184	8.70E+00	2.9E+00	1.78E-02	2.64E-03	5.79E-05
1.E-01	195.09	183	73	Ta-183	1.20E+02	7.8E+00	1.74E+01	1.52E+01	1.15E+01
4.E-01	195.09	182	73	Ta-182	2.76E+03	1.2E+01	3.43E-02	3.41E-02	3.36E-02
2.E+00	195.09	180	73	Ta-180	8.10E+00	1.2E+02	1.37E-02	1.76E-03	2.91E-05
9.E+00	195.09	178	73	Ta-178	1.00E-01	5.2E+02	2.52E-02	1.88E-74	1.04E-218
9.E+00	195.09	178	73	Ta-178	2.20E+00	5.2E+02	1.59E+00	8.40E-04	2.33E-10
2.E+01	195.09	177	73	Ta-177	5.52E+01	9.8E+02	7.55E-02	5.59E-02	3.06E-02
3.E+01	195.09	176	73	Ta-176	8.00E+00	1.7E+03	8.09E+00	1.02E+00	1.60E-02
4.E+01	195.09	175	73	Ta-175	1.10E+01	2.5E+03	4.37E+00	9.65E-01	4.71E-02
5.E+01	195.09	174	73	Ta-174	1.10E+00	3.1E+03	1.72E+01	4.77E-06	3.67E-19
4.E+01	195.09	173	73	Ta-173	3.70E+00	2.5E+03	3.06E+00	3.44E-02	4.35E-06
5.E-03	195.09	183	72	Hf-183	1.10E+00	3.0E-01	5.83E-04	1.62E-10	1.24E-23
4.E-02	195.09	181	72	Hf-181	1.07E+03	2.3E+00	6.55E-03	6.45E-03	6.25E-03
1.E-01	195.09	180	72	Hf-180	5.50E+00	7.2E+00	4.26E-03	2.08E-04	4.96E-07
8.E+00	195.09	175	72	Hf-175	1.68E+03	3.7E+02	5.90E-01	5.85E-01	5.73E-01
3.E+01	195.09	173	72	Hf-173	2.40E+01	1.5E+03	8.99E-01	4.50E-01	1.13E-01
4.E+01	195.09	172	72	Hf-172	4.38E+04	1.2E+02	3.08E-01	3.07E-01	3.07E-01
5.E+01	195.09	171	72	Hf-171	1.60E+01	2.7E+03	1.20E+00	4.26E-01	5.35E-02
2.E+01	195.09	169	72	Hf-169	1.50E+00	1.2E+03	1.76E+00	2.74E-05	6.62E-15
1.E-02	195.09	179	71	Lu-179	4.60E+00	8.4E-01	1.13E-04	3.06E-06	2.24E-09
1.E-01	195.09	177	71	Lu-177	3.72E+03	3.2E+00	2.85E-03	2.83E-03	2.81E-03
3.E-01	195.09	176	71	Lu-176	3.70E+00	1.8E+01	2.26E-03	2.54E-05	3.20E-09
2.E+00	195.09	174	71	Lu-174	3.15E+04	7.4E+00	3.13E-02	3.13E-02	3.13E-02
2.E+00	195.09	174	71	Lu-174	3.96E+03	4.6E+01	4.41E-02	4.39E-02	4.35E-02
4.E+00	195.09	173	71	Lu-173	1.23E+04	3.9E+01	3.06E-03	3.05E-03	3.04E-03
8.E+00	195.09	172	71	Lu-172	1.61E+02	4.6E+02	9.06E-01	8.17E-01	6.64E-01
1.E+01	195.09	171	71	Lu-171	1.99E+02	8.5E+02	1.02E+00	9.39E-01	7.95E-01
2.E+01	195.09	170	71	Lu-170	4.80E+01	1.4E+03	1.91E+00	1.35E+00	6.76E-01
4.E-03	195.09	177	70	Yb-177	1.90E+00	2.6E-01	8.71E-04	1.39E-07	3.56E-15
4.E-02	195.09	175	70	Yb-175	1.01E+02	2.3E+00	7.23E-04	6.13E-04	4.41E-04
8.E+00	195.09	169	70	Yb-169	7.68E+02	4.2E+02	5.04E-01	4.94E-01	4.73E-01
2.E+01	195.09	167	70	Yb-167	3.00E-01	1.3E+03	4.19E-01	3.80E-25	3.12E-73
3.E+01	195.09	166	70	Yb-166	5.52E+01	1.8E+03	1.42E-01	1.05E-01	5.75E-02

TABLE 1

Radioactivity Content And Exposure Rate From A 5 Cm Long Platinum Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus (195.09 Equals All Stable Isotopes of Pt)	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
1.E-02	195.09	173	69	Tm-173	8.20E+00	7.7E-01	1.47E-03	1.94E-04	3.38E-06
4.E-02	195.09	172	69	Tm-172	6.48E+01	2.3E+00	2.78E-02	2.15E-02	1.29E-02
1.E-01	195.09	171	69	Tm-171	1.66E+04	8.4E-01	8.09E-06	8.08E-06	8.06E-06
3.E-01	195.09	170	69	Tm-170	3.00E+03	9.2E+00	3.56E-04	3.54E-04	3.50E-04
2.E+00	195.09	168	69	Tm-168	2.04E+03	6.8E+01	1.54E-01	1.53E-01	1.50E-01
4.E+00	195.09	167	69	Tm-167	2.30E+02	2.2E+02	1.60E-01	1.49E-01	1.29E-01
7.E+00	195.09	166	69	Tm-166	7.70E+00	4.3E+02	2.85E+00	3.30E-01	4.41E-03
1.E+01	195.09	165	69	Tm-165	2.88E+01	7.7E+02	5.59E-01	3.14E-01	9.91E-02
3.E+01	195.09	163	69	Tm-163	1.80E+00	1.6E+03	1.54E+00	1.52E-04	1.47E-12
1.E-03	195.09	172	68	Er-172	4.80E+01	7.4E-02	1.49E-04	1.05E-04	5.27E-05
4.E-03	195.09	171	68	Er-171	7.50E+00	2.4E-01	3.94E-04	4.30E-05	5.13E-07
7.E+00	195.09	163	68	Er-163	1.20E+00	4.2E+02	1.57E+00	1.53E-06	1.46E-18
2.E+01	195.09	161	68	Er-161	3.10E+00	1.1E+03	4.51E+00	2.13E-02	4.73E-07
1.E+01	195.09	158	68	Er-158	2.50E+00	6.5E+02	2.22E+00	2.90E-03	4.92E-09
1.E-02	195.09	167	67	Ho-167	3.00E+00	7.7E-01	2.02E-04	7.97E-07	1.24E-11
4.E-02	195.09	166	67	Ho-166	2.64E+01	2.3E+00	7.39E-04	3.94E-04	1.12E-04
4.E-02	195.09	166	67	Ho-166	7.88E+08	6.8E-06	2.24E-08	2.24E-08	2.24E-08
3.E-01	195.09	164	67	Ho-164	6.00E-01	1.7E+01	2.19E-03	2.09E-15	1.89E-39
2.E+00	195.09	162	67	Ho-162	2.00E-01	1.0E+02	1.94E-03	1.68E-39	1.25E-111
2.E+00	195.09	162	67	Ho-162	2.64E+01	1.0E+02	6.17E-01	3.29E-01	9.35E-02
4.E+00	195.09	161	67	Ho-161	2.50E+00	2.1E+02	1.18E-01	1.54E-04	2.61E-10
7.E+00	195.09	160	67	Ho-160	5.00E-01	4.1E+02	2.00E-01	7.52E-16	1.06E-44
7.E+00	195.09	160	67	Ho-160	4.80E+00	4.1E+02	5.25E-01	1.65E-02	1.63E-05
1.E-03	195.09	166	66	Dy-166	8.16E+01	7.6E-02	2.22E-05	1.81E-05	1.20E-05
4.E-03	195.09	165	66	Dy-165	2.30E+00	2.5E-01	4.91E-06	3.59E-09	1.92E-15
2.E+00	195.09	159	66	Dy-159	3.46E+03	5.1E+01	4.89E-04	4.87E-04	4.82E-04
7.E+00	195.09	157	66	Dy-157	8.20E+00	4.1E+02	6.67E-01	8.79E-02	1.53E-03
2.E+01	195.09	155	66	Dy-155	1.00E+01	9.9E+02	1.53E+00	2.91E-01	1.05E-02
6.E+00	195.09	152	66	Dy-152	2.40E+00	3.2E+02	1.01E+00	9.95E-04	9.71E-10
1.E-03	195.09	163	65	Tb-163	6.50E+00	8.0E-02	1.30E-04	1.01E-05	6.08E-08
1.E-02	195.09	161	65	Tb-161	1.66E+02	8.5E-01	1.81E-04	1.64E-04	1.34E-04
4.E-02	195.09	160	65	Tb-160	1.75E+03	1.9E+00	9.74E-03	9.65E-03	9.47E-03
2.E+00	195.09	156	65	Tb-156	5.50E+00	1.1E+02	9.34E-03	4.56E-04	1.09E-06
2.E+00	195.09	156	65	Tb-156	1.30E+02	1.1E+02	1.06E-01	9.31E-02	7.20E-02
4.E+00	195.09	155	65	Tb-155	1.30E+02	2.2E+02	1.16E-01	1.02E-01	7.90E-02
7.E+00	195.09	154	65	Tb-154	2.10E+01	4.1E+02	2.92E-01	1.32E-01	2.72E-02
1.E+01	195.09	153	65	Tb-153	6.24E+01	6.7E+02	4.55E-01	3.48E-01	2.05E-01
2.E+01	195.09	152	65	Tb-152	1.74E+01	9.0E+02	2.99E+00	1.15E+00	1.71E-01
1.E+01	195.09	151	65	Tb-151	1.80E+01	7.4E+02	7.27E-01	2.89E-01	4.56E-02
4.E+00	195.09	149	65	Tb-149	4.10E+00	2.2E+02	2.18E-01	3.80E-03	1.15E-06
2.E+00	195.09	148	65	Tb-148	1.10E+00	9.6E+01	4.21E-01	1.17E-07	8.97E-21
5.E-03	195.09	159	64	Gd-159	1.80E+01	2.9E-01	2.02E-04	8.04E-05	1.27E-05
2.E+00	195.09	153	64	Gd-153	5.76E+03	3.7E+01	1.52E-02	1.52E-02	1.51E-02
7.E+00	195.09	151	64	Gd-151	2.88E+03	2.3E+02	4.45E-02	4.42E-02	4.37E-02
1.E+01	195.09	149	64	Gd-149	2.23E+02	7.9E+02	2.28E-01	2.12E-01	1.83E-01
5.E+00	195.09	147	64	Gd-147	2.40E+01	3.0E+02	3.50E-01	1.75E-01	4.39E-02
2.E+00	195.09	146	64	Gd-146	1.15E+03	1.2E+02	1.04E-01	1.02E-01	9.96E-02
1.E+00	195.09	145	64	Gd-145	4.00E-01	6.0E+01	6.41E-01	5.96E-19	5.14E-55

TABLE 1

Radioactivity Content And Exposure Rate From A 5 Cm Long Platinum Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, *mb*	Mass of Target Nucleus (195.09 Equals All Stable Isotopes of Pt)	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
2.E-03	195.09	157	63	Eu-157	1.52E+01	9.6E-02	1.54E-04	5.15E-05	5.79E-06
6.E-03	195.09	156	63	Eu-156	3.60E+02	3.2E-01	2.78E-03	2.66E-03	2.42E-03
2.E-02	195.09	155	63	Eu-155	1.58E+04	1.4E-01	3.81E-05	3.81E-05	3.80E-05
5.E-02	195.09	154	63	Eu-154	1.40E+05	5.1E-02	1.64E-04	1.64E-04	1.64E-04
4.E-01	195.09	152	63	Eu-152	9.30E+00	2.3E+01	1.07E-02	1.79E-03	5.03E-05
4.E-01	195.09	152	63	Eu-152	1.10E+05	4.7E-01	7.71E-04	7.71E-04	7.70E-04
2.E+00	195.09	150	63	Eu-150	1.28E+01	1.2E+02	3.48E-03	9.50E-04	7.09E-05
4.E+00	195.09	149	63	Eu-149	2.54E+03	1.4E+02	2.12E-01	2.11E-01	2.08E-01
7.E+00	195.09	148	63	Eu-148	1.30E+03	3.5E+02	1.73E+00	1.71E+00	1.66E+00
1.E+01	195.09	147	63	Eu-147	5.76E+02	6.0E+02	7.71E-01	7.49E-01	7.07E-01
1.E+01	195.09	146	63	Eu-146	1.10E+02	6.2E+02	4.35E+00	3.75E+00	2.77E+00
7.E+00	195.09	145	63	Eu-145	1.34E+02	3.9E+02	2.96E+00	2.61E+00	2.04E+00
4.E+00	195.09	144	63	Eu-144	3.00E-01	2.0E+02	1.02E+00	9.26E-25	7.61E-73
1.E-04	195.09	156	62	Sm-156	9.40E+00	8.1E-03	2.20E-06	3.77E-07	1.10E-08
5.E-04	195.09	155	62	Sm-155	4.00E-01	3.0E-02	1.65E-05	1.53E-23	1.32E-59
6.E-03	195.09	153	62	Sm-153	4.80E+01	3.6E-01	4.59E-05	3.24E-05	1.62E-05
7.E+00	195.09	145	62	Sm-145	8.16E+03	1.0E+02	4.99E-03	4.98E-03	4.96E-03
8.E+00	195.09	143	62	Sm-143	1.00E-01	4.7E+02	2.35E+00	1.75E-72	9.72E-217
2.E+00	195.09	141	62	Sm-141	4.80E+02	1.3E+02	6.61E-01	6.38E-01	5.96E-01
2.E-03	195.09	151	61	Pm-151	2.88E+01	1.3E-01	3.56E-04	2.00E-04	6.32E-05
7.E-03	195.09	150	61	Pm-150	2.70E+00	4.2E-01	2.75E-03	5.87E-06	2.67E-11
2.E-02	195.09	149	61	Pm-149	5.28E+01	1.3E+00	5.18E-05	3.78E-05	2.02E-05
7.E-02	195.09	148	61	Pm-148	1.30E+02	4.0E+00	7.78E-03	6.84E-03	5.30E-03
7.E-02	195.09	148	61	Pm-148	9.84E+02	3.6E+00	7.92E-03	7.79E-03	7.53E-03
1.E+00	195.09	145	61	Pm-145	1.58E+05	9.6E-01	1.86E-05	1.86E-05	1.86E-05
2.E+00	195.09	144	61	Pm-144	8.76E+03	3.2E+01	2.36E-01	2.36E-01	2.35E-01
4.E+00	195.09	143	61	Pm-143	6.36E+03	7.9E+01	1.23E-01	1.23E-01	1.22E-01
9.E+00	195.09	141	61	Pm-141	4.00E-01	5.0E+02	2.50E+00	2.32E-18	2.00E-54
5.E-05	195.09	151	60	Nd-151	2.00E-01	2.8E-03	1.60E-06	1.38E-42	1.03E-114
7.E-04	195.09	149	60	Nd-149	1.80E+00	4.2E-02	2.26E-05	2.22E-09	2.15E-17
9.E-03	195.09	147	60	Nd-147	1.11E+01	5.0E-01	3.34E-04	7.47E-05	3.75E-06
3.E+00	195.09	141	60	Nd-141	2.50E+00	1.5E+02	3.90E-02	5.08E-05	8.62E-11
7.E+00	195.09	139	60	Nd-139	5.20E+00	4.0E+02	1.78E+00	7.31E-02	1.23E-04
7.E+00	195.09	138	60	Nd-138	4.00E-01	3.9E+02	9.70E-01	9.01E-19	7.78E-55
9.E-04	195.09	146	59	Pr-146	4.00E-01	5.1E-02	2.75E-04	2.56E-22	2.21E-58
1.E-02	195.09	144	59	Pr-144	3.00E-01	6.0E-01	1.05E-04	9.54E-29	7.84E-77
9.E-02	195.09	142	59	Pr-142	1.92E+01	5.5E+00	1.71E-03	7.21E-04	1.28E-04
1.E+00	195.09	139	59	Pr-139	4.50E+00	8.2E+01	2.45E-02	6.11E-04	3.80E-07
3.E+00	195.09	138	59	Pr-138	2.00E+00	1.6E+02	4.75E-01	1.18E-04	7.20E-12
5.E+00	195.09	137	59	Pr-137	1.50E+00	2.7E+02	3.67E-01	5.71E-06	1.38E-15
6.E+00	195.09	136	59	Pr-136	1.10E+00	3.7E+02	7.68E-01	2.13E-07	1.64E-20
5.E+00	195.09	135	59	Pr-135	4.00E-01	2.9E+02	9.23E-01	8.57E-19	7.40E-55
2.E-05	195.09	146	58	Ce-146	2.00E-01	1.0E-03	1.45E-06	1.25E-42	9.31E-115
3.E-04	195.09	144	58	Ce-144	6.84E+03	4.8E-03	6.53E-07	6.52E-07	6.48E-07
1.E-03	195.09	143	58	Ce-143	3.36E+01	6.3E-02	9.07E-05	5.53E-05	2.06E-05
1.E-02	195.09	141	58	Ce-141	7.80E+02	7.1E-01	2.60E-04	2.54E-04	2.44E-04
1.E-01	195.09	139	58	Ce-139	3.36E+03	3.3E+00	2.23E-03	2.21E-03	2.19E-03
7.E-01	195.09	137	58	Ce-137	8.70E+00	4.2E+01	2.88E-03	4.26E-04	9.37E-06

TABLE 1

Radioactivity Content And Exposure Rate From A 5 Cm Long Platinum Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus (195.09 Equals All Stable Isotopes of Pt)	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
7.E-01	195.09	137	58	Ce-137	4.32E+01	4.2E+01	1.24E-01	8.42E-02	3.90E-02
3.E+00	195.09	135	58	Ce-135	1.70E+01	1.7E+02	8.36E-03	3.15E-03	4.46E-04
5.E+00	195.09	133	58	Ce-133	6.30E+00	3.1E+02	2.15E+00	1.54E-01	7.90E-04
3.E+00	195.09	132	58	Ce-132	4.20E+00	2.0E+02	9.96E-01	1.91E-02	7.02E-06
9.E-05	195.09	142	57	La-142	1.50E+00	5.4E-03	1.55E-05	2.42E-10	5.83E-20
4.E-04	195.09	141	57	La-141	3.90E+00	2.1E-02	2.89E-06	4.08E-08	8.17E-12
1.E-03	195.09	140	57	La-140	4.08E+01	8.0E-02	7.92E-04	5.27E-04	2.34E-04
1.E-01	195.09	136	57	La-136	2.00E-01	8.1E+00	1.34E-02	1.16E-38	8.62E-111
4.E-01	195.09	135	57	La-135	1.97E+01	2.1E+01	2.04E-03	8.79E-04	1.63E-04
8.E-01	195.09	134	57	La-134	1.00E-01	4.9E+01	1.61E-01	1.20E-73	6.69E-218
2.E+00	195.09	133	57	La-133	4.00E+00	1.0E+02	4.55E-01	7.16E-03	1.77E-06
3.E+00	195.09	132	57	La-132	1.50E+00	1.8E+02	9.05E-01	1.41E-05	3.40E-15
5.E+00	195.09	131	57	La-131	1.00E+00	2.7E+02	3.73E-01	2.29E-08	8.59E-23
1.E-06	195.09	142	56	Ba-142	2.00E-01	8.1E-05	1.02E-08	8.82E-45	6.57E-117
6.E-06	195.09	141	56	Ba-141	3.00E-01	3.8E-04	3.65E-08	3.31E-32	2.72E-80
3.E-05	195.09	140	56	Ba-140	3.07E+02	1.7E-03	3.37E-06	3.19E-06	2.86E-06
1.E-04	195.09	139	56	Ba-139	1.40E+00	7.0E-03	1.15E-06	8.12E-12	4.03E-22
2.E-02	195.09	135	56	Ba-135	2.88E+01	1.2E+00	1.62E-04	9.10E-05	2.87E-05
2.E-01	195.09	133	56	Ba-133	3.84E+01	1.0E+01	1.75E-03	1.14E-03	4.79E-04
2.E-01	195.09	133	56	Ba-133	7.01E+04	3.3E-01	5.64E-04	5.63E-04	5.63E-04
1.E+00	195.09	131	56	Ba-131	2.78E+02	5.7E+01	2.16E-01	2.03E-01	1.80E-01
3.E+00	195.09	129	56	Ba-129	2.40E+00	1.9E+02	1.40E-01	1.39E-04	1.35E-10
4.E+00	195.09	128	56	Ba-128	5.76E+01	2.4E+02	3.19E-01	2.39E-01	1.35E-01
1.E+00	195.09	126	56	Ba-126	1.70E+00	8.4E+01	5.36E-01	3.07E-05	1.00E-13
9.E-06	195.09	138	55	Cs-138	5.00E-01	5.0E-04	4.44E-06	1.67E-20	2.35E-49
4.E-05	195.09	137	55	Cs-137	2.63E+05	2.0E-05	6.36E-08	6.36E-08	6.35E-08
2.E-04	195.09	136	55	Cs-136	3.10E+02	9.4E-03	3.72E-05	3.53E-05	3.17E-05
2.E-03	195.09	134	55	Cs-134	2.90E+00	1.4E-01	2.41E-05	7.85E-08	8.33E-13
2.E-03	195.09	134	55	Cs-134	1.34E+04	2.2E-02	9.23E-05	9.22E-05	9.20E-05
3.E-02	195.09	132	55	Cs-132	1.56E+02	1.6E+00	5.08E-03	4.57E-03	3.69E-03
2.E-01	195.09	130	55	Cs-130	5.00E-01	1.3E+01	2.88E-02	1.08E-16	1.52E-45
5.E-01	195.09	129	55	Cs-129	3.12E+01	3.1E+01	6.40E-02	3.76E-02	1.30E-02
2.E+00	195.09	127	55	Cs-127	6.20E+00	1.3E+02	2.34E-01	1.61E-02	7.57E-05
3.E+00	195.09	125	55	Cs-125	7.00E-01	1.8E+02	4.59E-01	2.28E-11	5.62E-32
9.E-01	195.09	123	55	Cs-123	1.00E-01	5.0E+01	2.51E-01	1.87E-73	1.04E-217
1.E-07	195.09	138	54	Xe-138	3.00E-01	5.9E-06	2.40E-09	2.17E-33	1.79E-81
1.E-05	195.09	135	54	Xe-135	3.00E-01	6.9E-04	7.19E-07	6.52E-31	5.36E-79
1.E-05	195.09	135	54	Xe-135	8.40E+00	6.9E-04	8.47E-07	1.17E-07	2.25E-09
2.E-04	195.09	133	54	Xe-133	1.27E+02	1.3E-02	2.50E-06	2.19E-06	1.69E-06
2.E-04	195.09	133	54	Xe-133	5.52E+01	1.3E-02	1.50E-06	1.11E-06	6.07E-07
3.E-03	195.09	131	54	Xe-131	2.88E+02	1.9E-01	3.63E-06	3.43E-06	3.05E-06
4.E-02	195.09	129	54	Xe-129	1.92E+02	2.0E+00	5.94E-05	5.45E-05	4.59E-05
3.E-01	195.09	127	54	Xe-127	8.74E+02	1.5E+01	1.69E-02	1.66E-02	1.59E-02
1.E+00	195.09	125	54	Xe-125	1.80E+01	7.7E+01	3.57E-02	1.42E-02	2.24E-03
3.E+00	195.09	123	54	Xe-123	1.80E+00	1.8E+02	7.45E-01	7.33E-05	7.09E-13
2.E+00	195.09	122	54	Xe-122	1.90E+01	1.3E+02	8.00E-02	3.34E-02	5.81E-03
1.E+00	195.09	121	54	Xe-121	7.00E-01	6.7E+01	3.46E-01	1.72E-11	4.24E-32
1.E-07	195.09	135	53	I-135	6.70E+00	8.3E-06	7.90E-08	6.62E-09	4.65E-11

TABLE 1

Radioactivity Content And Exposure Rate From A 5 Cm Long Platinum Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus (195.09 Equals All Stable Isotopes of Pt)	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
7.E-07	195.09	134	53	I-134	9.00E-01	4.3E-05	3.40E-07	3.29E-15	3.08E-31
4.E-06	195.09	133	53	I-133	2.10E+01	2.1E-04	5.45E-07	2.47E-07	5.08E-08
2.E-05	195.09	132	53	I-132	2.30E+00	9.8E-04	8.60E-06	6.29E-09	3.36E-15
7.E-05	195.09	131	53	I-131	1.94E+02	4.3E-03	8.08E-06	7.42E-06	6.25E-06
3.E-04	195.09	130	53	I-130	1.25E+01	1.8E-02	1.89E-04	5.01E-05	3.51E-06
4.E-03	195.09	128	53	I-128	4.00E-01	2.6E-01	1.23E-04	1.14E-22	9.86E-59
5.E-02	195.09	126	53	I-126	3.17E+02	2.7E+00	5.50E-03	5.22E-03	4.70E-03
1.E-01	195.09	125	53	I-125	1.44E+03	6.2E+00	3.01E-04	2.97E-04	2.91E-04
3.E-01	195.09	124	53	I-124	1.01E+02	2.0E+01	7.73E-02	6.55E-02	4.71E-02
8.E-01	195.09	123	53	I-123	1.30E+01	4.5E+01	3.51E-02	9.79E-03	7.61E-04
2.E+00	195.09	121	53	I-121	1.40E+00	1.4E+02	2.48E-01	1.75E-06	8.67E-17
2.E+00	195.09	120	53	I-120	1.40E+00	1.4E+02	6.43E-01	4.53E-06	2.25E-16
4.E-08	195.09	133	52	Te-133	1.00E+00	2.2E-06	4.68E-10	2.87E-17	1.08E-31
2.E-07	195.09	132	52	Te-132	7.92E+01	1.2E-05	1.35E-08	1.10E-08	7.21E-09
1.E-06	195.09	131	52	Te-131	4.00E-01	6.2E-05	4.32E-08	4.01E-26	3.46E-62
1.E-06	195.09	131	52	Te-131	2.88E+01	6.2E-05	8.16E-08	4.58E-08	1.45E-08
2.E-05	195.09	129	52	Te-129	1.10E+00	1.4E-03	1.52E-06	4.21E-13	3.24E-26
2.E-05	195.09	129	52	Te-129	7.92E+02	1.4E-03	3.34E-06	3.27E-06	3.13E-06
4.E-04	195.09	127	52	Te-127	9.40E+00	2.6E-02	5.05E-07	8.63E-08	2.52E-09
4.E-04	195.09	127	52	Te-127	2.52E+03	1.6E-02	3.35E-06	3.33E-06	3.28E-06
6.E-02	195.09	123	52	Te-123	2.50E+03	2.2E+00	7.35E-04	7.30E-04	7.20E-04
4.E-01	195.09	121	52	Te-121	3.70E+03	1.2E+01	3.76E-02	3.75E-02	3.71E-02
4.E-01	195.09	121	52	Te-121	4.08E+02	2.5E+01	3.53E-02	3.39E-02	3.12E-02
2.E+00	195.09	119	52	Te-119	1.60E+01	9.7E+01	1.70E-01	6.04E-02	7.57E-03
2.E+00	195.09	119	52	Te-119	1.13E+02	9.7E+01	3.21E-01	2.77E-01	2.07E-01
2.E+00	195.09	117	52	Te-117	1.10E+00	1.0E+02	3.25E-01	9.01E-08	6.93E-21
9.E-01	195.09	116	52	Te-116	2.50E+00	5.2E+01	5.46E-01	7.11E-04	1.21E-09
3.E-07	195.09	129	51	Sb-129	4.30E+00	1.8E-05	2.84E-08	5.98E-10	2.64E-13
2.E-06	195.09	128	51	Sb-128	9.00E+00	9.3E-05	2.40E-07	3.79E-08	9.46E-10
2.E-06	195.09	128	51	Sb-128	2.00E-01	9.3E-05	1.65E-07	1.42E-43	1.06E-115
8.E-06	195.09	127	51	Sb-127	9.36E+01	4.6E-04	2.02E-06	1.69E-06	1.19E-06
4.E-05	195.09	126	51	Sb-126	3.00E-01	2.1E-03	4.53E-06	4.10E-30	3.37E-78
4.E-05	195.09	126	51	Sb-126	3.00E+02	2.1E-03	1.85E-05	1.75E-05	1.56E-05
7.E-04	195.09	124	51	Sb-124	1.44E+03	3.1E-02	2.20E-04	2.17E-04	2.12E-04
9.E-03	195.09	122	51	Sb-122	6.72E+01	5.2E-01	1.13E-03	8.80E-04	5.37E-04
9.E-02	195.09	120	51	Sb-120	1.39E+02	5.0E+00	2.95E-02	2.62E-02	2.06E-02
2.E-01	195.09	119	51	Sb-119	3.84E+01	1.3E+01	2.31E-03	1.50E-03	6.32E-04
5.E-01	195.09	118	51	Sb-118	5.10E+00	3.1E+01	1.71E-01	6.58E-03	9.77E-06
1.E+00	195.09	117	51	Sb-117	2.80E+00	6.3E+01	5.69E-02	1.51E-04	1.07E-09
2.E+00	195.09	116	51	Sb-116	3.00E-01	1.0E+02	5.75E-01	5.21E-25	4.28E-73
2.E+00	195.09	116	51	Sb-116	1.00E+00	1.0E+02	4.66E-01	2.86E-08	1.07E-22
5.E-07	195.09	126	50	Sn-126	8.76E+08	7.3E-11	3.87E-13	3.87E-13	3.87E-13
2.E-06	195.09	125	50	Sn-125	2.00E-01	1.4E-04	2.44E-07	2.10E-43	1.57E-115
2.E-06	195.09	125	50	Sn-125	2.26E+02	1.4E-04	3.99E-08	3.71E-08	3.20E-08
6.E-05	195.09	123	50	Sn-123	3.00E+03	1.8E-03	8.48E-08	8.44E-08	8.34E-08
6.E-05	195.09	123	50	Sn-123	7.00E-01	3.2E-03	2.55E-06	1.26E-16	3.12E-37
1.E-03	195.09	121	50	Sn-121	2.19E+05	6.1E-04	1.59E-07	1.59E-07	1.59E-07
1.E-02	195.09	119	50	Sn-119	6.00E+03	2.4E-01	5.15E-05	5.13E-05	5.10E-05

TABLE 1

Radioactivity Content And Exposure Rate From A 5 Cm Long Platinum Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus (195.09 Equals All Stable Isotopes of Pt)	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
1.E-01	195.09	117	50	Sn-117	3.36E+02	6.8E+00	2.63E-03	2.51E-03	2.27E-03
2.E+00	195.09	113	50	Sn-113	2.83E+03	5.8E+01	1.83E-01	1.82E-01	1.79E-01
7.E-01	195.09	111	50	Sn-111	6.00E-01	3.8E+01	5.54E-02	5.27E-14	4.78E-38
3.E-01	195.09	110	50	Sn-110	4.00E+00	1.6E+01	1.63E-01	2.56E-03	6.33E-07
9.E-02	195.09	109	50	Sn-109	3.00E-01	5.5E+00	7.82E-03	7.09E-27	5.83E-75
6.E-03	195.09	117	49	In-117	7.00E-01	3.2E-01	5.58E-04	2.77E-14	6.84E-35
6.E-03	195.09	117	49	In-117	1.90E+00	3.2E-01	1.79E-04	2.86E-08	7.31E-16
2.E-02	195.09	116	49	In-116	9.00E-01	1.1E+00	6.64E-03	6.43E-11	6.02E-27
6.E-02	195.09	115	49	In-115	4.50E+00	3.4E+00	2.55E-03	6.35E-05	3.96E-08
2.E-01	195.09	114	49	In-114	1.20E+03	7.9E+00	1.46E-03	1.44E-03	1.40E-03
4.E-01	195.09	113	49	In-113	1.70E+00	2.2E+01	1.41E-02	8.05E-07	2.63E-15
8.E-01	195.09	112	49	In-112	4.00E-01	4.6E+01	1.74E-02	1.62E-20	1.40E-56
8.E-01	195.09	112	49	In-112	2.00E-01	4.6E+01	3.35E-02	2.90E-38	2.16E-110
1.E+00	195.09	111	49	In-111	6.72E+01	7.8E+01	1.52E-01	1.19E-01	7.26E-02
1.E+00	195.09	110	49	In-110	4.90E+00	8.3E+01	8.62E-01	2.91E-02	3.31E-05
8.E-01	195.09	109	49	In-109	4.30E+00	4.8E+01	1.28E-01	2.68E-03	1.18E-06
4.E-01	195.09	108	49	In-108	7.00E-01	2.1E+01	8.06E-02	4.00E-12	9.87E-33
4.E-01	195.09	108	49	In-108	9.00E-01	2.1E+01	1.85E-01	1.79E-09	1.68E-25
1.E-01	195.09	107	49	In-107	6.00E-01	7.9E+00	4.76E-02	4.54E-14	4.11E-38
1.E-04	195.09	117	48	Cd-117	2.90E+00	8.1E-03	1.76E-05	5.73E-08	6.08E-13
2.E-03	195.09	115	48	Cd-115	1.03E+03	1.2E-01	1.18E-05	1.16E-05	1.12E-05
2.E-03	195.09	115	48	Cd-115	5.52E+01	1.4E-01	3.63E-04	2.69E-04	1.47E-04
2.E-01	195.09	111	48	Cd-111	8.00E-01	1.3E+01	8.25E-03	7.95E-12	7.39E-30
9.E-01	195.09	109	48	Cd-109	1.14E+04	1.0E+01	3.86E-04	3.85E-04	3.84E-04
1.E+00	195.09	107	48	Cd-107	6.50E+00	5.6E+01	1.08E-03	8.40E-05	5.07E-07
2.E-01	195.09	105	48	Cd-105	9.00E-01	1.1E+01	2.71E-02	2.62E-10	2.46E-26
6.E-02	195.09	104	48	Cd-104	1.00E+00	3.6E+00	2.08E-03	1.27E-10	4.77E-25
5.E-05	195.09	115	47	Ag-115	4.00E-01	2.9E-03	3.41E-07	3.17E-25	2.74E-61
9.E-04	195.09	113	47	Ag-113	5.30E+00	5.5E-02	4.08E-05	1.78E-06	3.37E-09
4.E-03	195.09	112	47	Ag-112	3.20E+00	2.1E-01	4.03E-04	2.25E-06	6.97E-11
1.E-02	195.09	111	47	Ag-111	1.80E+02	7.5E-01	1.02E-04	9.29E-05	7.72E-05
4.E-02	195.09	110	47	Ag-110	6.07E+03	7.6E-01	4.36E-03	4.35E-03	4.32E-03
1.E+00	195.09	106	47	Ag-106	1.99E+02	6.0E+01	2.48E-01	2.28E-01	1.93E-01
1.E+00	195.09	105	47	Ag-105	9.60E+02	5.6E+01	2.33E-01	2.29E-01	2.21E-01
6.E-01	195.09	104	47	Ag-104	1.20E+00	3.4E+01	1.37E-01	1.34E-07	1.27E-19
3.E-01	195.09	103	47	Ag-103	1.10E+00	1.5E+01	3.51E-02	9.74E-09	7.49E-22
8.E-05	195.09	112	46	Pd-112	2.10E+01	5.0E-03	2.01E-06	9.14E-07	1.88E-07
4.E-04	195.09	111	46	Pd-111	5.50E+00	2.2E-02	3.58E-05	1.75E-06	4.17E-09
4.E-04	195.09	111	46	Pd-111	4.00E-01	2.2E-02	4.26E-06	3.96E-24	3.42E-60
6.E-03	195.09	109	46	Pd-109	1.35E+01	3.4E-01	1.31E-05	3.84E-06	3.28E-07
1.E+00	195.09	103	46	Pd-103	4.08E+02	5.9E+01	3.74E-02	3.59E-02	3.31E-02
3.E-01	195.09	101	46	Pd-101	8.50E+00	1.9E+01	2.44E-02	3.46E-03	6.96E-05
1.E-01	195.09	100	46	Pd-100	9.84E+01	7.2E+00	3.14E-03	2.65E-03	1.89E-03
4.E-02	195.09	99	46	Pd-99	4.00E-01	2.3E+00	2.92E-02	2.72E-20	2.34E-56
3.E-03	195.09	107	45	Rh-107	4.00E-01	1.5E-01	2.04E-04	1.89E-22	1.63E-58
9.E-03	195.09	106	45	Rh-106	2.20E+00	5.4E-01	2.65E-03	1.39E-06	3.87E-13
3.E-02	195.09	105	45	Rh-105	3.60E+01	1.8E+00	2.76E-04	1.74E-04	6.92E-05
2.E-01	195.09	103	45	Rh-103	1.00E+00	1.3E+01	2.91E-03	1.78E-10	6.69E-25

TABLE 1

Radioactivity Content And Exposure Rate From A 5 Cm Long Platinum Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus (195.09 Equals All Stable Isotopes of Pt)	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
5.E-01	195.09	102	45	Rh-102	4.94E+03	1.0E+01	4.79E-02	4.77E-02	4.74E-02
8.E-01	195.09	101	45	Rh-101	4.38E+04	2.4E+00	1.89E-03	1.89E-03	1.89E-03
8.E-01	195.09	101	45	Rh-101	1.08E+02	4.7E+01	3.52E-02	3.01E-02	2.22E-02
8.E-01	195.09	100	45	Rh-100	2.10E+01	4.4E+01	3.55E-01	1.61E-01	3.31E-02
4.E-01	195.09	99	45	Rh-99	4.70E+00	2.4E+01	1.96E-02	5.72E-04	4.88E-07
4.E-01	195.09	99	45	Rh-99	3.84E+02	2.4E+01	8.37E-02	8.02E-02	7.35E-02
2.E-01	195.09	98	45	Rh-98	1.00E-01	9.7E+00	7.88E-02	5.87E-74	3.26E-218
1.E-03	195.09	105	44	Ru-105	4.40E+00	6.4E-02	2.42E-04	5.55E-06	2.92E-09
1.E-02	195.09	103	44	Ru-103	9.60E+02	8.0E-01	1.93E-03	1.90E-03	1.83E-03
5.E-01	195.09	97	44	Ru-97	6.96E+01	2.8E+01	5.13E-03	4.04E-03	2.51E-03
8.E-02	195.09	95	44	Ru-95	1.70E+00	4.5E+00	9.96E-03	5.69E-07	1.86E-15
1.E-04	195.09	104	43	Tc-104	3.00E-01	5.9E-03	4.44E-06	4.02E-30	3.31E-78
7.E-03	195.09	101	43	Tc-101	2.00E-01	4.2E-01	6.30E-04	5.44E-40	4.05E-112
7.E-02	195.09	99	43	Tc-99	6.00E+00	4.2E+00	1.29E-03	8.10E-05	3.19E-07
2.E-01	195.09	98	43	Tc-98	1.31E+10	1.9E-06	1.29E-08	1.29E-08	1.29E-08
4.E-01	195.09	97	43	Tc-97	2.18E+03	1.5E+01	7.16E-04	7.11E-04	7.00E-04
6.E-01	195.09	96	43	Tc-96	9.00E-01	3.7E+01	1.18E-02	1.14E-10	1.07E-26
6.E-01	195.09	96	43	Tc-96	1.03E+02	3.7E+01	4.46E-01	3.80E-01	2.75E-01
5.E-01	195.09	95	43	Tc-95	2.00E+01	3.1E+01	5.95E-02	2.59E-02	4.93E-03
5.E-01	195.09	95	43	Tc-95	1.44E+03	2.5E+01	2.39E-02	2.36E-02	2.30E-02
3.E-01	195.09	94	43	Tc-94	9.00E-01	1.6E+01	1.59E-01	1.54E-09	1.44E-25
1.E-01	195.09	93	43	Tc-93	2.70E+00	6.0E+00	2.68E-02	5.72E-05	2.60E-10
2.E-04	195.09	101	42	Mo-101	3.00E-01	1.1E-02	3.78E-05	3.43E-29	2.82E-77
3.E-03	195.09	99	42	Mo-99	6.72E+01	1.9E-01	2.32E-04	1.82E-04	1.11E-04
6.E-01	195.09	93	42	Mo-93	6.90E+00	3.3E+01	1.81E-01	1.63E-02	1.32E-04
1.E-01	195.09	91	42	Mo-91	3.00E-01	7.8E+00	3.89E-02	3.52E-26	2.90E-74
4.E-02	195.09	90	42	Mo-90	6.00E+00	2.6E+00	1.40E-02	8.76E-04	3.45E-06
2.E-03	195.09	97	41	Nb-97	1.20E+00	8.8E-02	2.87E-04	2.80E-10	2.67E-22
6.E-03	195.09	96	41	Nb-96	2.30E+01	3.4E-01	3.73E-03	1.81E-03	4.27E-04
2.E-02	195.09	95	41	Nb-95	8.40E+02	1.1E+00	4.13E-03	4.05E-03	3.89E-03
2.E-02	195.09	95	41	Nb-95	9.12E+01	1.2E+00	1.36E-04	1.13E-04	7.86E-05
6.E-02	195.09	94	41	Nb-94	1.00E-01	3.5E+00	7.15E-04	5.33E-76	2.96E-220
6.E-02	195.09	94	41	Nb-94	2.10E+08	3.9E-05	2.99E-07	2.99E-07	2.99E-07
2.E-01	195.09	93	41	Nb-93	3.24E+04	6.3E-01	4.84E-05	4.84E-05	4.83E-05
3.E-01	195.09	92	41	Nb-92	2.42E+02	1.9E+01	8.85E-02	8.26E-02	7.20E-02
5.E-01	195.09	91	41	Nb-91	1.44E+03	2.4E+01	5.90E-02	5.83E-02	5.70E-02
4.E-01	195.09	90	41	Nb-90	1.46E+01	2.1E+01	4.23E-01	1.36E-01	1.39E-02
2.E-01	195.09	89	41	Nb-89	1.90E+00	9.8E+00	2.20E-02	3.52E-06	8.99E-14
2.E-01	195.09	89	41	Nb-89	1.00E+00	9.8E+00	1.41E-02	8.65E-10	3.25E-24
3.E-05	195.09	97	40	Zr-97	1.70E+01	1.7E-03	9.47E-07	3.56E-07	5.05E-08
7.E-04	195.09	95	40	Zr-95	1.56E+03	3.0E-02	1.06E-04	1.05E-04	1.03E-04
4.E-01	195.09	89	40	Zr-89	9.12E+01	2.3E+01	3.01E-02	2.51E-02	1.74E-02
4.E-01	195.09	88	40	Zr-88	2.04E+03	1.6E+01	3.00E-02	2.97E-02	2.93E-02
2.E-01	195.09	87	40	Zr-87	1.70E+00	1.2E+01	5.62E-02	3.21E-06	1.05E-14
8.E-02	195.09	86	40	Zr-86	1.70E+01	4.6E+00	1.18E-01	4.44E-02	6.30E-03
6.E-05	195.09	94	39	Y-94	3.00E-01	3.4E-03	8.13E-06	7.37E-30	6.06E-78
3.E-04	195.09	93	39	Y-93	1.01E+01	1.7E-02	9.89E-06	1.91E-06	7.12E-08
1.E-03	195.09	92	39	Y-92	3.50E+00	7.4E-02	4.74E-05	4.12E-07	3.11E-11

TABLE 1

Radioactivity Content And Exposure Rate From A 5 Cm Long Platinum Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus (195.09 Equals All Stable Isotopes of Pt)	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
5.E-03	195.09	91	39	Y-91	8.00E-01	2.9E-01	3.96E-04	3.81E-13	3.54E-31
2.E-02	195.09	90	39	Y-90	3.10E+00	1.0E+00	4.98E-04	2.35E-06	5.22E-11
1.E-01	195.09	88	39	Y-88	2.59E+03	4.7E+00	6.12E-02	6.08E-02	6.00E-02
3.E-01	195.09	87	39	Y-87	1.40E+01	1.6E+01	1.21E-02	3.71E-03	3.45E-04
3.E-01	195.09	87	39	Y-87	7.92E+01	1.6E+01	3.81E-02	3.09E-02	2.03E-02
4.E-01	195.09	86	39	Y-86	1.46E+01	2.3E+01	2.99E-01	9.59E-02	9.86E-03
2.E-01	195.09	85	39	Y-85	2.70E+00	1.4E+01	8.57E-02	1.83E-04	8.30E-10
1.E-01	195.09	84	39	Y-84	3.70E+00	5.8E+00	2.88E-02	3.24E-04	4.09E-08
2.E-05	195.09	92	38	Sr-92	2.70E+00	1.4E-03	8.40E-06	1.79E-08	8.13E-14
1.E-04	195.09	91	38	Sr-91	9.70E+00	7.1E-03	3.69E-05	6.66E-06	2.17E-07
3.E-02	195.09	87	38	Sr-87	2.90E+00	1.8E+00	1.34E-03	4.37E-06	4.64E-11
2.E-01	195.09	85	38	Sr-85	1.20E+00	1.1E+01	6.46E-03	6.30E-09	6.00E-21
2.E-01	195.09	85	38	Sr-85	1.54E+03	8.7E+00	2.16E-02	2.14E-02	2.09E-02
3.E-01	195.09	83	38	Sr-83	3.36E+01	1.5E+01	1.17E-01	7.15E-02	2.66E-02
5.E-05	195.09	89	37	Rb-89	2.00E-01	2.9E-03	3.25E-05	2.80E-41	2.09E-113
3.E-04	195.09	88	37	Rb-88	3.00E-01	1.5E-02	1.04E-04	9.39E-29	7.72E-77
5.E-03	195.09	86	37	Rb-86	4.49E+02	2.7E-01	1.28E-04	1.23E-04	1.14E-04
5.E-02	195.09	84	37	Rb-84	7.92E+02	2.8E+00	1.13E-02	1.11E-02	1.06E-02
1.E-01	195.09	83	37	Rb-83	1.99E+03	5.0E+00	1.28E-02	1.27E-02	1.24E-02
2.E-01	195.09	82	37	Rb-82	6.30E+00	1.4E+01	9.90E-02	7.09E-03	3.64E-05
3.E-01	195.09	81	37	Rb-81	4.70E+00	1.6E+01	3.12E-02	9.10E-04	7.76E-07
5.E-02	195.09	79	37	Rb-79	4.00E-01	3.2E+00	1.63E-02	1.51E-20	1.31E-56
3.E-06	195.09	88	36	Kr-88	2.80E+00	2.0E-04	1.85E-06	4.91E-09	3.46E-14
2.E-05	195.09	87	36	Kr-87	1.30E+00	1.2E-03	3.21E-06	9.08E-12	7.27E-23
5.E-04	195.09	85	36	Kr-85	4.40E+00	3.1E-02	1.38E-05	3.16E-07	1.66E-10
5.E-04	195.09	85	36	Kr-85	9.37E+04	7.6E-04	7.34E-09	7.34E-09	7.34E-09
9.E-03	195.09	83	36	Kr-83	1.90E+00	5.1E-01	2.08E-04	3.33E-08	8.50E-16
3.E-01	195.09	79	36	Kr-79	3.36E+01	1.6E+01	1.12E-02	6.80E-03	2.53E-03
7.E-02	195.09	77	36	Kr-77	1.20E+00	3.9E+00	1.95E-02	1.90E-08	1.81E-20
2.E-02	195.09	76	36	Kr-76	1.48E+01	1.2E+00	1.62E-03	5.28E-04	5.60E-05
5.E-05	195.09	84	35	Br-84	1.00E-01	2.7E-03	2.80E-05	2.08E-77	1.16E-221
5.E-05	195.09	84	35	Br-84	5.00E-01	2.7E-03	5.84E-06	2.19E-20	3.09E-49
2.E-04	195.09	83	35	Br-83	2.40E+00	1.4E-02	4.05E-07	4.00E-10	3.90E-16
1.E-03	195.09	82	35	Br-82	3.60E+01	6.5E-02	8.31E-04	5.24E-04	2.08E-04
2.E-02	195.09	80	35	Br-80	3.00E-01	9.5E-01	1.19E-04	1.08E-28	8.88E-77
2.E-02	195.09	80	35	Br-80	4.40E+00	9.5E-01	1.01E-04	2.31E-06	1.22E-09
1.E-01	195.09	78	35	Br-78	1.00E-01	6.9E+00	3.44E-02	2.56E-74	1.42E-218
2.E-01	195.09	77	35	Br-77	5.76E+01	1.2E+01	4.77E-02	3.57E-02	2.01E-02
2.E-01	195.09	76	35	Br-76	1.70E+01	1.1E+01	4.54E-02	1.71E-02	2.42E-03
8.E-02	195.09	75	35	Br-75	1.70E+00	4.8E+00	3.20E-02	1.83E-06	5.98E-15
3.E-02	195.09	74	35	Br-74	6.00E-01	1.6E+00	1.21E-02	1.15E-14	1.04E-38
3.E-06	195.09	83	34	Se-83	4.00E-01	1.8E-04	6.22E-07	5.78E-25	4.99E-61
2.E-01	195.09	75	34	Se-75	2.88E+03	5.2E+00	1.65E-02	1.64E-02	1.62E-02
1.E-01	195.09	73	34	Se-73	7.10E+00	5.6E+00	1.47E-02	1.42E-03	1.32E-05
3.E-02	195.09	72	34	Se-72	2.02E+02	2.0E+00	4.07E-04	3.74E-04	3.18E-04
9.E-03	195.09	71	34	Se-71	1.00E-01	5.5E-01	2.96E-03	2.20E-75	1.22E-219
2.E-03	195.09	70	34	Se-70	7.00E-01	1.2E-01	6.02E-04	2.99E-14	7.38E-35
5.E-05	195.09	79	33	As-79	1.00E-01	2.7E-03	1.24E-06	9.22E-79	5.12E-223

TABLE 1

Radioactivity Content And Exposure Rate From A 5 Cm Long Platinum Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus (195.09 Equals All Stable Isotopes of Pt)	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
2.E-04	195.09	78	33	As-78	1.50E+00	1.4E-02	2.15E-05	3.33E-10	8.05E-20
1.E-03	195.09	77	33	As-77	3.84E+01	6.7E-02	3.91E-06	2.54E-06	1.07E-06
5.E-03	195.09	76	33	As-76	2.64E+01	2.8E-01	5.77E-04	3.07E-04	8.74E-05
5.E-02	195.09	74	33	As-74	4.25E+02	2.9E+00	1.02E-02	9.81E-03	9.07E-03
1.E-01	195.09	73	33	As-73	1.82E+03	4.8E+00	1.90E-02	1.89E-02	1.85E-02
2.E-01	195.09	72	33	As-72	2.64E+01	1.1E+01	8.93E-02	4.76E-02	1.35E-02
1.E-01	195.09	71	33	As-71	6.24E+01	6.4E+00	1.56E-02	1.20E-02	7.03E-03
4.E-02	195.09	70	33	As-70	8.00E-01	2.5E+00	3.98E-02	3.84E-11	3.56E-29
1.E-02	195.09	69	33	As-69	2.00E-01	7.1E-01	4.36E-03	3.76E-39	2.81E-111
3.E-03	195.09	68	33	As-68	1.00E-01	1.6E-01	8.13E-04	6.06E-76	3.37E-220
2.E-05	195.09	77	32	Ge-77	1.13E+01	1.1E-03	2.06E-06	4.75E-07	2.51E-08
6.E-04	195.09	75	32	Ge-75	1.40E+00	3.3E-02	6.02E-06	4.24E-11	2.11E-21
1.E-01	195.09	69	32	Ge-69	4.08E+01	6.9E+00	5.37E-02	3.57E-02	1.58E-02
2.E-02	195.09	67	32	Ge-67	3.00E-01	9.1E-01	4.54E-03	4.12E-27	3.38E-75
4.E-03	195.09	66	32	Ge-66	2.40E+00	2.2E-01	1.35E-03	1.34E-06	1.31E-12
5.E-05	195.09	74	31	Ga-74	1.00E-01	2.9E-03	2.54E-05	1.89E-77	1.05E-221
3.E-04	195.09	73	31	Ga-73	4.80E+00	1.6E-02	2.28E-05	7.17E-07	7.08E-10
1.E-03	195.09	72	31	Ga-72	1.41E+01	7.5E-02	4.84E-04	1.49E-04	1.41E-05
2.E-02	195.09	70	31	Ga-70	4.00E-01	1.1E+00	5.21E-05	4.84E-23	4.18E-59
1.E-01	195.09	68	31	Ga-68	1.10E+00	6.4E+00	2.88E-02	7.98E-09	6.14E-22
1.E-01	195.09	67	31	Ga-67	7.92E+01	7.3E+00	9.55E-03	7.74E-03	5.09E-03
6.E-02	195.09	66	31	Ga-66	9.50E+00	3.4E+00	2.63E-02	4.59E-03	1.39E-04
2.E-02	195.09	65	31	Ga-65	2.00E-01	1.1E+00	7.71E-03	6.65E-39	4.96E-111
2.E-05	195.09	72	30	Zn-72	4.56E+01	1.2E-03	8.55E-07	5.94E-07	2.87E-07
1.E-04	195.09	71	30	Zn-71	4.00E+00	7.3E-03	5.26E-05	8.28E-07	2.05E-10
3.E-03	195.09	69	30	Zn-69	1.39E+01	1.7E-01	1.80E-04	5.45E-05	5.00E-06
1.E-01	195.09	65	30	Zn-65	5.88E+03	2.3E+00	6.36E-03	6.34E-03	6.30E-03
2.E-02	195.09	63	30	Zn-63	6.00E-01	1.4E+00	5.66E-03	5.39E-15	4.88E-39
6.E-03	195.09	62	30	Zn-62	9.30E+00	3.6E-01	5.12E-04	8.58E-05	2.41E-06
2.E-03	195.09	67	29	Cu-67	6.00E+01	8.9E-02	6.97E-05	5.29E-05	3.04E-05
6.E-03	195.09	66	29	Cu-66	1.00E-01	3.6E-01	1.66E-04	1.24E-76	6.86E-221
6.E-02	195.09	64	29	Cu-64	1.28E+01	3.2E+00	3.29E-03	8.99E-04	6.71E-05
7.E-02	195.09	62	29	Cu-62	2.00E-01	4.3E+00	2.10E-02	1.81E-38	1.35E-110
3.E-02	195.09	61	29	Cu-61	3.30E+00	1.6E+00	6.74E-03	4.40E-05	1.87E-09
8.E-03	195.09	60	29	Cu-60	4.00E-01	4.5E-01	4.88E-03	4.54E-21	3.92E-57
8.E-04	195.09	65	28	Ni-65	2.50E+00	4.6E-02	1.32E-04	1.73E-07	2.93E-13
2.E-03	195.09	57	28	Ni-57	3.60E+01	1.2E-01	1.17E-03	7.35E-04	2.92E-04
3.E-04	195.09	56	28	Ni-56	1.46E+02	2.0E-02	1.52E-04	1.36E-04	1.08E-04
2.E-03	195.09	62	27	Co-62	2.00E-01	1.1E-01	1.57E-03	1.36E-39	1.01E-111
8.E-03	195.09	61	27	Co-61	1.70E+00	4.5E-01	1.57E-04	9.00E-09	2.94E-17
2.E-02	195.09	60	27	Co-60	4.64E+04	7.1E-02	8.66E-04	8.65E-04	8.65E-04
2.E-02	195.09	60	27	Co-60	2.00E-01	1.4E+00	4.48E-04	3.87E-40	2.88E-112
8.E-02	195.09	58	27	Co-58	9.00E+00	4.6E+00	2.66E-03	4.21E-04	1.05E-05
8.E-02	195.09	58	27	Co-58	1.70E+03	3.4E+00	1.61E-02	1.59E-02	1.56E-02
4.E-02	195.09	57	27	Co-57	6.41E+03	6.6E-01	3.91E-04	3.90E-04	3.88E-04
1.E-02	195.09	56	27	Co-56	1.85E+03	4.8E-01	6.02E-03	5.97E-03	5.86E-03
3.E-03	195.09	55	27	Co-55	1.80E+01	1.5E-01	1.34E-03	5.34E-04	8.44E-05
1.E-03	195.09	60	26	Fe-60	8.76E+08	1.6E-07	1.62E-10	1.62E-10	1.62E-10

TABLE 1

Radioactivity Content And Exposure Rate From A 5 Cm Long Platinum Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus (195.09 Equals All Stable Isotopes of Pt)	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
5.E-03	195.09	59	26	Fe-59	1.08E+03	2.3E-01	1.36E-03	1.34E-03	1.30E-03
3.E-03	195.09	53	26	Fe-53	1.00E-01	1.9E-01	9.41E-04	7.01E-76	3.90E-220
6.E-04	195.09	52	26	Fe-52	8.30E+00	3.3E-02	1.18E-04	1.60E-05	2.93E-07
1.E-02	195.09	56	25	Mn-56	2.60E+00	5.9E-01	5.19E-03	8.73E-06	2.47E-11
6.E-02	195.09	54	25	Mn-54	7.54E+03	9.3E-01	3.82E-03	3.81E-03	3.79E-03
2.E-02	195.09	52	25	Mn-52	4.00E-01	9.3E-01	1.09E-02	1.01E-20	8.73E-57
2.E-02	195.09	52	25	Mn-52	1.37E+02	9.3E-01	7.94E-03	7.03E-03	5.52E-03
4.E-03	195.09	51	25	Mn-51	7.00E-01	2.3E-01	1.15E-03	5.70E-14	1.41E-34
5.E-02	195.09	51	24	Cr-51	6.67E+02	2.6E+00	4.08E-04	3.98E-04	3.79E-04
5.E-03	195.09	49	24	Cr-49	7.00E-01	2.8E-01	1.08E-03	5.37E-14	1.32E-34
9.E-04	195.09	48	24	V-48	2.30E+01	5.2E-02	1.07E-04	5.22E-05	1.23E-05
2.E-02	195.09	48	23	V-48	3.89E+02	1.2E+00	1.70E-02	1.63E-02	1.49E-02
6.E-03	195.09	47	23	V-47	5.00E-01	3.3E-01	1.63E-03	6.11E-18	8.61E-47
4.E-04	195.09	51	22	Ti-51	1.00E-01	2.6E-02	4.39E-05	3.27E-77	1.82E-221
7.E-03	195.09	45	22	Ti-45	3.10E+00	3.8E-01	1.58E-03	7.45E-06	1.65E-10
1.E-03	195.09	44	22	Ti-44	8.76E+06	2.0E-05	1.30E-08	1.30E-08	1.30E-08
1.E-03	195.09	48	21	Sc-48	4.32E+01	7.4E-02	1.21E-03	8.23E-04	3.81E-04
6.E-03	195.09	47	21	Sc-47	8.16E+01	3.2E-01	1.77E-04	1.45E-04	9.62E-05
2.E-02	195.09	46	21	Sc-46	2.02E+03	7.1E-01	7.00E-03	6.94E-03	6.83E-03
2.E-02	195.09	44	21	Sc-44	5.76E+01	1.4E+00	9.27E-04	6.95E-04	3.90E-04
7.E-03	195.09	43	21	Sc-43	3.90E+00	4.3E-01	2.12E-03	3.00E-05	6.00E-09
2.E-06	195.09	49	20	Ca-49	1.00E-01	1.2E-04	1.85E-06	1.38E-78	7.65E-223
1.E-04	195.09	47	20	Ca-47	1.13E+02	7.1E-03	3.43E-05	2.96E-05	2.21E-05
4.E-04	195.09	44	19	K-44	4.00E-01	2.3E-02	1.60E-04	1.48E-22	1.28E-58
2.E-03	195.09	43	19	K-43	2.20E+01	1.2E-01	5.68E-04	2.67E-04	5.90E-05
8.E-03	195.09	42	19	K-42	1.24E+01	4.9E-01	6.48E-04	1.70E-04	1.17E-05
2.E-03	195.09	38	19	K-38	1.00E-01	1.2E-01	1.82E-03	1.36E-75	7.54E-220
1.E-03	195.09	41	18	Ar-41	1.80E+00	7.3E-02	4.56E-04	4.48E-08	4.34E-16
7.E-04	195.09	39	17	Cl-39	9.00E-01	4.3E-02	2.03E-04	1.96E-12	1.84E-28
4.E-03	195.09	38	17	Cl-38	6.00E-01	2.1E-01	1.53E-03	1.46E-15	1.32E-39
3.E-03	195.09	34	17	Cl-34	6.00E-01	1.5E-01	5.94E-04	5.65E-16	5.12E-40
6.E-05	195.09	38	16	S-38	2.90E+00	3.5E-03	3.07E-05	1.00E-07	1.06E-12
4.E-04	195.09	37	16	S-37	1.00E-01	2.5E-02	3.70E-05	2.76E-77	1.53E-221
3.E-03	195.09	29	13	Al-29	1.00E-01	1.6E-01	1.08E-03	8.05E-76	4.47E-220
4.E-03	195.09	26	13	Al-26	6.13E+09	8.1E-08	1.07E-09	1.07E-09	1.07E-09
3.E-04	195.09	28	12	Mg-28	2.12E+01	1.7E-02	1.04E-04	4.76E-05	9.94E-06
2.E-03	195.09	27	12	Mg-27	2.00E-01	1.1E-01	4.59E-04	3.96E-40	2.95E-112
5.E-03	195.09	24	11	Na-24	1.50E+01	3.1E-01	6.26E-03	2.07E-03	2.26E-04
4.E-03	195.09	22	11	Na-22	2.28E+04	2.3E-02	2.43E-04	2.42E-04	2.42E-04
4.E-03	195.09	18	9	F-18	1.80E+00	2.5E-01	1.16E-03	1.14E-07	1.11E-15
6.E-04	195.09	13	7	N-13	2.00E-01	3.5E-02	1.76E-04	1.52E-40	1.13E-112
6.E-04	195.09	11	6	C-11	3.00E-01	3.3E-02	1.65E-04	1.50E-28	1.23E-76
4.E-04	195.09	7	4	Be-7	1.28E+03	2.2E-02	6.04E-06	5.96E-06	5.81E-06
Sum 2.1E+03						Sum 1.2E+05	Sum 2.42E+02	Sum 8.69E+01	Sum 5.39E+01

TABLE 2

Radioactivity Content And Exposure Rate From A 15 Cm Long Nickel Target Hit With High Intensity Proton Beam (60 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 168 Hours Decay, R/h
2.E+01	64	64	29	Cu-64	1.28E+01	8.6E+01	8.73E-02	2.38E-02	9.92E-06
3.E+01	64	62	29	Cu-62	2.00E-01	1.1E+02	5.57E-01	4.81E-37	1.99E-253
1.E+01	64	61	29	Cu-61	3.30E+00	4.3E+01	1.79E-01	1.17E-03	8.96E-17
3.E+00	64	60	29	Cu-60	4.00E-01	1.2E+01	1.29E-01	1.20E-19	7.74E-128
3.E+01	62	62	29	Cu-62	2.00E-01	4.4E+02	2.18E+00	1.89E-36	7.81E-253
4.E+00	62	60	29	Cu-60	4.00E-01	4.7E+01	5.08E-01	4.72E-19	3.04E-127
4.E+00	61	60	29	Cu-60	4.00E-01	1.6E+01	1.78E-01	1.65E-19	1.06E-127
4.E+00	60	60	29	Cu-60	4.00E-01	3.9E+02	4.22E+00	3.92E-18	2.52E-126
1.E+00	58.71	57	28	Ni-57	3.60E+01	4.4E+02	4.23E+00	2.67E+00	1.67E-01
2.E-01	58.71	56	28	Ni-56	1.46E+02	1.6E+01	1.18E-01	1.05E-01	5.33E-02
1.E+00	58.71	57	28	Ni-57	3.60E+01	8.8E+02	8.46E+00	5.33E+00	3.35E-01
2.E-01	58.71	56	28	Ni-56	1.46E+02	1.5E+02	1.11E+00	9.87E-01	5.00E-01
4.E+01	58.71	58	27	Co-58	9.00E+00	3.3E+04	1.93E+01	3.05E+00	4.74E-05
4.E+01	58.71	58	27	Co-58	1.70E+03	2.5E+04	1.17E+02	1.15E+02	1.09E+02
2.E+01	58.71	57	27	Co-57	6.41E+03	4.8E+03	2.83E+00	2.82E+00	2.78E+00
7.E+00	58.71	56	27	Co-56	1.85E+03	3.5E+03	4.37E+01	4.33E+01	4.10E+01
1.E+00	58.71	55	27	Co-55	1.80E+01	1.1E+03	9.75E+00	3.87E+00	1.53E-02
2.E+00	58.71	53	26	Fe-53	1.00E-01	1.4E+03	6.82E+00	5.09E-72	0.00E+00
3.E-01	58.71	52	26	Fe-52	8.30E+00	2.4E+02	8.58E-01	1.16E-01	7.09E-07
6.E+00	58.71	56	25	Mn-56	2.60E+00	4.2E+03	3.76E+01	6.33E-02	1.43E-18
3.E+01	58.71	54	25	Mn-54	7.54E+03	6.7E+03	2.77E+01	2.76E+01	2.73E+01
9.E+00	58.71	52	25	Mn-52	4.00E-01	6.8E+03	7.89E+01	7.33E-17	4.72E-125
9.E+00	58.71	52	25	Mn-52	1.37E+02	6.8E+03	5.76E+01	5.10E+01	2.46E+01
2.E+00	58.71	51	25	Mn-51	7.00E-01	1.7E+03	8.32E+00	4.13E-10	6.20E-72
3.E+01	58.71	51	24	Cr-51	6.67E+02	1.9E+04	2.96E+00	2.89E+00	2.49E+00
3.E+00	58.71	49	24	Cr-49	7.00E-01	2.0E+03	7.83E+00	3.89E-10	5.84E-72
5.E-01	58.71	48	24	V-48	2.30E+01	3.7E+02	7.79E-01	3.78E-01	4.97E-03
1.E+01	58.71	48	23	V-48	3.89E+02	8.6E+03	1.23E+02	1.18E+02	9.13E+01
3.E+00	58.71	47	23	V-47	5.00E-01	2.4E+03	1.18E+01	4.43E-14	1.24E-100
3.E-01	58.71	51	22	Ti-51	1.00E-01	1.9E+02	3.18E-01	2.37E-73	0.00E+00
4.E+00	58.71	45	22	Ti-45	3.10E+00	2.8E+03	1.15E+01	5.40E-02	5.92E-16
7.E-01	58.71	44	22	Ti-44	8.76E+06	1.5E-01	9.41E-05	9.41E-05	9.41E-05
7.E-01	58.71	48	21	Sc-48	4.32E+01	5.4E+02	8.76E+00	5.96E+00	5.94E-01
3.E+00	58.71	47	21	Sc-47	8.16E+01	2.3E+03	1.28E+00	1.05E+00	3.09E-01
1.E+01	58.71	46	21	Sc-46	2.02E+03	5.2E+03	5.07E+01	5.03E+01	4.79E+01
1.E+01	58.71	44	21	Sc-44	5.76E+01	1.0E+04	6.72E+00	5.04E+00	8.93E-01
4.E+00	58.71	43	21	Sc-43	3.90E+00	3.2E+03	1.54E+01	2.18E-01	1.74E-12
1.E-03	58.71	49	20	Ca-49	1.00E-01	8.5E-01	1.34E-02	9.98E-75	0.00E+00
7.E-02	58.71	47	20	Ca-47	1.13E+02	5.1E+01	2.49E-01	2.15E-01	8.88E-02
2.E-01	58.71	44	19	K-44	4.00E-01	1.7E+02	1.16E+00	1.08E-18	6.92E-127
1.E+00	58.71	43	19	K-43	2.20E+01	8.9E+02	4.12E+00	1.94E+00	2.09E-02
5.E+00	58.71	42	19	K-42	1.24E+01	3.5E+03	4.70E+00	1.23E+00	3.98E-04
1.E+00	58.71	38	19	K-38	1.00E-01	8.7E+02	1.32E+01	9.84E-72	0.00E+00
7.E-01	58.71	41	18	Ar-41	1.80E+00	5.3E+02	3.30E+00	3.25E-04	2.95E-28
4.E-01	58.71	39	17	Cl-39	9.00E-01	3.1E+02	1.47E+00	1.42E-08	1.17E-56
2.E+00	58.71	38	17	Cl-38	6.00E-01	1.5E+03	1.11E+01	1.06E-11	7.89E-84
1.E+00	58.71	34	17	Cl-34	6.00E-01	1.1E+03	4.30E+00	4.10E-12	3.05E-84
3.E-02	58.71	38	16	S-38	2.90E+00	2.6E+01	2.23E-01	7.25E-04	8.66E-19
2.E-01	58.71	37	16	S-37	1.00E-01	1.8E+02	2.69E-01	2.00E-73	0.00E+00
2.E+00	58.71	29	13	Al-29	1.00E-01	1.2E+03	7.83E+00	5.84E-72	0.00E+00

TABLE 2

Radioactivity Content And Exposure Rate From A 15 Cm Long Nickel Target Hit With High Intensity Proton Beam (60 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 168 Hours Decay, R/h
2.E+00	58.71	26	13	Al-26	6.13E+09	5.8E-04	7.73E-06	7.73E-06	7.73E-06
2.E-01	58.71	28	12	Mg-28	2.12E+01	1.3E+02	7.56E-01	3.46E-01	3.14E-03
1.E+00	58.71	27	12	Mg-27	2.00E-01	7.7E+02	3.33E+00	2.87E-36	1.19E-252
3.E+00	58.71	24	11	Na-24	1.50E+01	2.3E+03	4.54E+01	1.50E+01	1.96E-02
2.E+00	58.71	22	11	Na-22	2.28E+04	1.6E+02	1.76E+00	1.76E+00	1.75E+00
2.E+00	58.71	18	9	F-18	1.80E+00	1.8E+03	8.43E+00	8.30E-04	7.52E-28
3.E-01	58.71	13	7	N-13	2.00E-01	2.6E+02	1.28E+00	1.10E-36	4.56E-253
3.E-01	58.71	11	6	C-11	3.00E-01	2.4E+02	1.20E+00	1.09E-24	6.04E-169
3.E-01	58.71	7	4	Be-7	1.28E+03	1.6E+02	4.38E-02	4.32E-02	4.00E-02
Sum 2.9E+02						Sum 1.7E+05	Sum 7.75E+02	Sum 4.58E+02	Sum 3.51E+02

TABLE 3

Radioactivity Content And Exposure Rate From A 5 Cm Long Gold Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h
6.E+01	197	197	80	Hg-197	6.48E+01	3.5E+03	3.03E-01	2.35E-01
6.E+01	197	197	80	Hg-197	4.08E+01	3.5E+03	3.37E-01	2.24E-01
1.E+02	197	195	80	Hg-195	9.60E+00	7.6E+03	1.61E+01	2.85E+00
1.E+02	197	195	80	Hg-195	4.08E+01	7.6E+03	7.02E+00	4.67E+00
1.E+02	197	193	80	Hg-193	1.10E+01	6.5E+03	1.57E+01	3.47E+00
1.E+02	197	193	80	Hg-193	6.00E+00	6.5E+03	8.75E+00	5.49E-01
7.E+01	197	192	80	Hg-192	5.00E+00	4.1E+03	4.76E+00	1.72E-01
4.E+01	197	191	80	Hg-191	1.00E+00	2.3E+03	2.78E+00	1.71E-07
2.E+01	197	196	79	Au-196	9.70E+00	9.4E+02	5.17E-01	9.33E-02
2.E+01	197	196	79	Au-196	1.49E+02	9.4E+02	1.04E+00	9.33E-01
3.E+01	197	195	79	Au-195	4.39E+03	7.2E+02	1.73E-01	1.72E-01
5.E+01	197	194	79	Au-194	3.90E+01	3.0E+03	8.57E+00	5.60E+00
1.E+02	197	192	79	Au-192	3.90E+01	6.5E+03	1.86E+01	1.22E+01
6.E-01	197	197	78	Pt-197	1.40E+00	3.5E+01	1.72E+00	1.21E-05
6.E-01	197	197	78	Pt-197	1.99E+01	3.5E+01	2.35E-01	1.02E-01
3.E+00	197	195	78	Pt-195	9.84E+01	1.9E+02	1.04E-01	8.80E-02
4.E+01	197	191	78	Pt-191	1.05E+02	2.6E+03	1.42E+00	1.22E+00
1.E+02	197	189	78	Pt-189	1.08E+01	5.6E+03	3.08E+00	6.62E-01
1.E+02	197	188	78	Pt-188	2.40E+02	6.1E+03	3.38E+00	3.15E+00
5.E-01	197	194	77	Ir-194	1.90E+01	3.0E+01	1.65E-02	6.86E-03
1.E+00	197	193	77	Ir-193	2.86E+02	7.1E+01	1.38E-02	1.30E-02
3.E+00	197	192	77	Ir-192	5.69E+06	6.6E-02	2.44E-04	2.44E-04
3.E+00	197	192	77	Ir-192	1.78E+03	1.2E+02	1.98E-01	1.96E-01
1.E+01	197	190	77	Ir-190	3.20E+00	7.0E+02	2.58E+00	1.44E-02
1.E+01	197	190	77	Ir-190	2.95E+02	7.0E+02	8.19E-01	7.74E-01
2.E+01	197	189	77	Ir-189	3.19E+02	1.3E+03	1.28E+00	1.22E+00
4.E+01	197	188	77	Ir-188	4.08E+01	2.3E+03	4.88E+00	3.25E+00
6.E+01	197	187	77	Ir-187	1.06E+01	3.5E+03	7.51E+00	1.57E+00
8.E+01	197	186	77	Ir-186	1.58E+01	4.8E+03	5.20E+00	1.82E+00
9.E+01	197	185	77	Ir-185	1.39E+01	5.1E+03	4.49E+00	1.36E+00
6.E+01	197	184	77	Ir-184	3.20E+00	3.6E+03	2.35E+00	1.31E-02
1.E+00	197	193	77	Os-193	3.12E+01	7.1E+01	3.59E-02	2.11E-02
4.E-01	197	191	76	Os-191	3.60E+02	2.6E+01	1.63E-02	1.56E-02
1.E+00	197	190	76	Os-190	2.00E-01	6.2E+01	2.32E-01	2.00E-37
3.E+01	197	185	76	Os-185	2.26E+03	1.3E+03	4.04E+00	4.01E+00
7.E+01	197	183	76	Os-183	1.34E+01	4.2E+03	5.88E+00	1.70E+00
7.E+01	197	183	76	Os-183	9.80E+00	4.2E+03	6.94E+00	1.27E+00
7.E+01	197	182	76	Os-182	2.10E+01	4.2E+03	9.49E+00	4.30E+00
2.E-01	197	189	75	Re-189	2.30E+01	8.7E+00	2.37E-03	1.15E-03
4.E-01	197	188	75	Re-188	1.70E+01	2.2E+01	3.90E-03	1.47E-03
2.E+00	197	186	75	Re-186	8.88E+01	1.3E+02	2.07E-02	1.72E-02
1.E+01	197	184	75	Re-184	9.12E+02	5.1E+02	2.17E+00	2.13E+00
1.E+01	197	184	75	Re-184	4.06E+03	2.4E+02	1.44E+00	1.44E+00
2.E+01	197	183	75	Re-183	1.68E+03	7.8E+02	6.72E-01	6.65E-01
3.E+01	197	182	75	Re-182	3.12E+02	1.8E+03	8.73E+00	8.28E+00
3.E+01	197	182	75	Re-182	6.48E+01	1.8E+03	3.77E+00	2.92E+00
5.E+01	197	181	75	Re-181	1.90E+01	2.8E+03	4.99E+00	2.08E+00
6.E+01	197	180	75	Re-180	1.99E+01	3.7E+03	2.03E+00	8.81E-01
4.E+01	197	178	75	Re-178	2.00E-01	2.3E+03	1.14E+01	9.82E-36
2.E+01	197	177	75	Re-177	3.00E-01	1.3E+03	6.47E+00	5.86E-24

TABLE 3

Radioactivity Content And Exposure Rate From A 5 Cm Long Gold Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h
5.E-02	197	187	74	W-187	2.40E+01	2.8E+00	7.43E-03	3.72E-03
9.E+00	197	181	74	W-181	3.00E+03	2.7E+02	2.89E-02	2.87E-02
3.E+01	197	179	74	W-179	7.00E-01	1.6E+03	9.07E-01	4.50E-11
3.E+01	197	179	74	W-179	1.00E-01	1.6E+03	8.75E-01	6.52E-73
4.E+01	197	178	74	W-178	5.28E+02	2.4E+03	4.95E-01	4.80E-01
5.E+01	197	176	74	W-176	2.30E+00	2.8E+03	1.35E+00	9.88E-04
5.E-03	197	186	73	Ta-186	2.00E-01	3.0E-01	1.75E-04	1.51E-40
2.E-02	197	185	73	Ta-185	8.00E-01	8.9E-01	7.12E-04	6.87E-13
4.E-02	197	184	73	Ta-184	8.70E+00	2.5E+00	1.58E-02	2.34E-03
1.E-01	197	183	73	Ta-183	1.20E+02	7.0E+00	1.55E+01	1.35E+01
3.E-01	197	182	73	Ta-182	2.76E+03	1.0E+01	3.05E-02	3.03E-02
2.E+00	197	180	73	Ta-180	8.10E+00	1.0E+02	1.21E-02	1.56E-03
8.E+00	197	178	73	Ta-178	1.00E-01	4.6E+02	2.24E-02	1.67E-74
8.E+00	197	178	73	Ta-178	2.20E+00	4.6E+02	1.42E+00	7.47E-04
1.E+01	197	177	73	Ta-177	5.52E+01	8.7E+02	6.71E-02	4.97E-02
3.E+01	197	176	73	Ta-176	8.00E+00	1.5E+03	7.20E+00	9.03E-01
4.E+01	197	175	73	Ta-175	1.10E+01	2.2E+03	3.88E+00	8.58E-01
5.E+01	197	174	73	Ta-174	1.10E+00	2.8E+03	1.53E+01	4.24E-06
4.E+01	197	173	73	Ta-173	3.70E+00	2.2E+03	2.72E+00	3.06E-02
5.E-03	197	183	72	Hf-183	1.10E+00	2.7E-01	5.19E-04	1.44E-10
4.E-02	197	181	72	Hf-181	1.07E+03	2.1E+00	5.83E-03	5.74E-03
1.E-01	197	180	72	Hf-180	5.50E+00	6.4E+00	3.79E-03	1.85E-04
7.E+00	197	175	72	Hf-175	1.68E+03	3.2E+02	5.25E-01	5.20E-01
2.E+01	197	173	72	Hf-173	2.40E+01	1.4E+03	7.99E-01	4.00E-01
3.E+01	197	172	72	Hf-172	4.38E+04	1.0E+02	2.73E-01	2.73E-01
4.E+01	197	171	72	Hf-171	1.60E+01	2.4E+03	1.07E+00	3.79E-01
2.E+01	197	169	72	Hf-169	1.50E+00	1.1E+03	1.57E+00	2.44E-05
1.E-02	197	179	71	Lu-179	4.60E+00	7.4E-01	1.01E-04	2.72E-06
1.E-01	197	177	71	Lu-177	3.72E+03	2.8E+00	2.53E-03	2.52E-03
3.E-01	197	176	71	Lu-176	3.70E+00	1.6E+01	2.01E-03	2.25E-05
2.E+00	197	174	71	Lu-174	3.15E+04	6.6E+00	2.79E-02	2.78E-02
2.E+00	197	174	71	Lu-174	3.96E+03	4.1E+01	3.92E-02	3.90E-02
4.E+00	197	173	71	Lu-173	1.23E+04	3.5E+01	2.72E-03	2.71E-03
7.E+00	197	172	71	Lu-172	1.61E+02	4.1E+02	8.05E-01	7.26E-01
1.E+01	197	171	71	Lu-171	1.99E+02	7.6E+02	9.08E-01	8.35E-01
2.E+01	197	170	71	Lu-170	4.80E+01	1.3E+03	1.70E+00	1.20E+00
4.E-03	197	177	70	Yb-177	1.90E+00	2.3E-01	7.74E-04	1.24E-07
4.E-02	197	175	70	Yb-175	1.01E+02	2.1E+00	6.42E-04	5.45E-04
7.E+00	197	169	70	Yb-169	7.68E+02	3.7E+02	4.49E-01	4.39E-01
2.E+01	197	167	70	Yb-167	3.00E-01	1.2E+03	3.73E-01	3.38E-25
3.E+01	197	166	70	Yb-166	5.52E+01	1.6E+03	1.26E-01	9.34E-02
1.E-02	197	173	69	Tm-173	8.20E+00	6.8E-01	1.31E-03	1.73E-04
4.E-02	197	172	69	Tm-172	6.48E+01	2.0E+00	2.47E-02	1.91E-02
1.E-01	197	171	69	Tm-171	1.66E+04	7.4E-01	7.19E-06	7.18E-06
3.E-01	197	170	69	Tm-170	3.00E+03	8.2E+00	3.16E-04	3.14E-04
2.E+00	197	168	69	Tm-168	2.04E+03	6.0E+01	1.37E-01	1.36E-01
3.E+00	197	167	69	Tm-167	2.30E+02	1.9E+02	1.43E-01	1.33E-01
7.E+00	197	166	69	Tm-166	7.70E+00	3.8E+02	2.53E+00	2.93E-01
1.E+01	197	165	69	Tm-165	2.88E+01	6.8E+02	4.97E-01	2.79E-01
3.E+01	197	163	69	Tm-163	1.80E+00	1.5E+03	1.37E+00	1.35E-04

TABLE 3

Radioactivity Content And Exposure Rate From A 5 Cm Long Gold Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h
1.E-03	197	172	68	Er-172	4.80E+01	6.6E-02	1.32E-04	9.36E-05
4.E-03	197	171	68	Er-171	7.50E+00	2.2E-01	3.50E-04	3.82E-05
6.E+00	197	163	68	Er-163	1.20E+00	3.7E+02	1.39E+00	1.36E-06
2.E+01	197	161	68	Er-161	3.10E+00	1.0E+03	4.01E+00	1.89E-02
1.E+01	197	158	68	Er-158	2.50E+00	5.7E+02	1.98E+00	2.57E-03
1.E-02	197	167	67	Ho-167	3.00E+00	6.9E-01	1.80E-04	7.08E-07
4.E-02	197	166	67	Ho-166	2.64E+01	2.1E+00	6.57E-04	3.50E-04
4.E-02	197	166	67	Ho-166	7.88E+08	6.1E-06	1.99E-08	1.99E-08
3.E-01	197	164	67	Ho-164	6.00E-01	1.5E+01	1.95E-03	1.85E-15
2.E+00	197	162	67	Ho-162	2.00E-01	8.9E+01	1.73E-03	1.49E-39
2.E+00	197	162	67	Ho-162	2.64E+01	8.9E+01	5.49E-01	2.92E-01
3.E+00	197	161	67	Ho-161	2.50E+00	1.9E+02	1.05E-01	1.37E-04
6.E+00	197	160	67	Ho-160	5.00E-01	3.7E+02	1.78E-01	6.69E-16
6.E+00	197	160	67	Ho-160	4.80E+00	3.7E+02	4.67E-01	1.47E-02
1.E-03	197	166	66	Dy-166	8.16E+01	6.8E-02	1.97E-05	1.61E-05
4.E-03	197	165	66	Dy-165	2.30E+00	2.3E-01	4.37E-06	3.19E-09
2.E+00	197	159	66	Dy-159	3.46E+03	4.5E+01	4.35E-04	4.33E-04
6.E+00	197	157	66	Dy-157	8.20E+00	3.7E+02	5.93E-01	7.82E-02
2.E+01	197	155	66	Dy-155	1.00E+01	8.8E+02	1.36E+00	2.59E-01
5.E+00	197	152	66	Dy-152	2.40E+00	2.9E+02	8.96E-01	8.85E-04
1.E-03	197	163	65	Tb-163	6.50E+00	7.1E-02	1.15E-04	8.96E-06
1.E-02	197	161	65	Tb-161	1.66E+02	7.6E-01	1.61E-04	1.46E-04
4.E-02	197	160	65	Tb-160	1.75E+03	1.7E+00	8.66E-03	8.58E-03
2.E+00	197	156	65	Tb-156	5.50E+00	9.5E+01	8.30E-03	4.05E-04
2.E+00	197	156	65	Tb-156	1.30E+02	9.5E+01	9.41E-02	8.28E-02
3.E+00	197	155	65	Tb-155	1.30E+02	2.0E+02	1.03E-01	9.08E-02
6.E+00	197	154	65	Tb-154	2.10E+01	3.7E+02	2.59E-01	1.18E-01
1.E+01	197	153	65	Tb-153	6.24E+01	6.0E+02	4.04E-01	3.10E-01
1.E+01	197	152	65	Tb-152	1.74E+01	8.0E+02	2.66E+00	1.02E+00
1.E+01	197	151	65	Tb-151	1.80E+01	6.5E+02	6.46E-01	2.57E-01
3.E+00	197	149	65	Tb-149	4.10E+00	1.9E+02	1.94E-01	3.37E-03
1.E+00	197	148	65	Tb-148	1.10E+00	8.5E+01	3.74E-01	1.04E-07
4.E-03	197	159	64	Gd-159	1.80E+01	2.6E-01	1.80E-04	7.15E-05
2.E+00	197	153	64	Gd-153	5.76E+03	3.3E+01	1.35E-02	1.35E-02
6.E+00	197	151	64	Gd-151	2.88E+03	2.0E+02	3.95E-02	3.93E-02
1.E+01	197	149	64	Gd-149	2.23E+02	7.0E+02	2.03E-01	1.88E-01
5.E+00	197	147	64	Gd-147	2.40E+01	2.7E+02	3.11E-01	1.56E-01
2.E+00	197	146	64	Gd-146	1.15E+03	1.1E+02	9.24E-02	9.11E-02
9.E-01	197	145	64	Gd-145	4.00E-01	5.3E+01	5.70E-01	5.30E-19
1.E-03	197	157	63	Eu-157	1.52E+01	8.5E-02	1.37E-04	4.58E-05
5.E-03	197	156	63	Eu-156	3.60E+02	2.9E-01	2.47E-03	2.36E-03
2.E-02	197	155	63	Eu-155	1.58E+04	1.3E-01	3.39E-05	3.38E-05
5.E-02	197	154	63	Eu-154	1.40E+05	4.5E-02	1.46E-04	1.46E-04
3.E-01	197	152	63	Eu-152	9.30E+00	2.0E+01	9.50E-03	1.59E-03
3.E-01	197	152	63	Eu-152	1.10E+05	4.2E-01	6.85E-04	6.85E-04
2.E+00	197	150	63	Eu-150	1.28E+01	1.1E+02	3.09E-03	8.45E-04
4.E+00	197	149	63	Eu-149	2.54E+03	1.3E+02	1.89E-01	1.88E-01
6.E+00	197	148	63	Eu-148	1.30E+03	3.1E+02	1.54E+00	1.52E+00
9.E+00	197	147	63	Eu-147	5.76E+02	5.4E+02	6.86E-01	6.66E-01
1.E+01	197	146	63	Eu-146	1.10E+02	5.5E+02	3.87E+00	3.33E+00

TABLE 3

Radioactivity Content And Exposure Rate From A 5 Cm Long Gold Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h
6.E+00	197	145	63	Eu-145	1.34E+02	3.5E+02	2.63E+00	2.32E+00
3.E+00	197	144	63	Eu-144	3.00E-01	1.8E+02	9.08E-01	8.23E-25
1.E-04	197	156	62	Sm-156	9.40E+00	7.2E-03	1.96E-06	3.35E-07
5.E-04	197	155	62	Sm-155	4.00E-01	2.7E-02	1.47E-05	1.36E-23
6.E-03	197	153	62	Sm-153	4.80E+01	3.2E-01	4.08E-05	2.88E-05
6.E+00	197	145	62	Sm-145	8.16E+03	9.2E+01	4.43E-03	4.42E-03
7.E+00	197	143	62	Sm-143	1.00E-01	4.2E+02	2.09E+00	1.56E-72
2.E+00	197	141	62	Sm-141	4.80E+02	1.2E+02	5.87E-01	5.67E-01
2.E-03	197	151	61	Pm-151	2.88E+01	1.1E-01	3.17E-04	1.78E-04
6.E-03	197	150	61	Pm-150	2.70E+00	3.8E-01	2.45E-03	5.22E-06
2.E-02	197	149	61	Pm-149	5.28E+01	1.2E+00	4.61E-05	3.37E-05
6.E-02	197	148	61	Pm-148	1.30E+02	3.5E+00	6.92E-03	6.08E-03
6.E-02	197	148	61	Pm-148	9.84E+02	3.2E+00	7.04E-03	6.92E-03
1.E+00	197	145	61	Pm-145	1.58E+05	8.5E-01	1.65E-05	1.65E-05
2.E+00	197	144	61	Pm-144	8.76E+03	2.9E+01	2.10E-01	2.10E-01
4.E+00	197	143	61	Pm-143	6.36E+03	7.0E+01	1.09E-01	1.09E-01
8.E+00	197	141	61	Pm-141	4.00E-01	4.5E+02	2.22E+00	2.06E-18
4.E-05	197	151	60	Nd-151	2.00E-01	2.5E-03	1.42E-06	1.23E-42
6.E-04	197	149	60	Nd-149	1.80E+00	3.7E-02	2.01E-05	1.98E-09
8.E-03	197	147	60	Nd-147	1.11E+01	4.4E-01	2.97E-04	6.64E-05
2.E+00	197	141	60	Nd-141	2.50E+00	1.3E+02	3.46E-02	4.51E-05
6.E+00	197	139	60	Nd-139	5.20E+00	3.5E+02	1.58E+00	6.50E-02
6.E+00	197	138	60	Nd-138	4.00E-01	3.5E+02	8.62E-01	8.01E-19
8.E-04	197	146	59	Pr-146	4.00E-01	4.5E-02	2.45E-04	2.27E-22
9.E-03	197	144	59	Pr-144	3.00E-01	5.4E-01	9.35E-05	8.48E-29
8.E-02	197	142	59	Pr-142	1.92E+01	4.9E+00	1.52E-03	6.41E-04
1.E+00	197	139	59	Pr-139	4.50E+00	7.3E+01	2.18E-02	5.43E-04
2.E+00	197	138	59	Pr-138	2.00E+00	1.4E+02	4.22E-01	1.05E-04
4.E+00	197	137	59	Pr-137	1.50E+00	2.4E+02	3.27E-01	5.08E-06
6.E+00	197	136	59	Pr-136	1.10E+00	3.3E+02	6.83E-01	1.89E-07
4.E+00	197	135	59	Pr-135	4.00E-01	2.5E+02	8.20E-01	7.62E-19
2.E-05	197	146	58	Ce-146	2.00E-01	8.9E-04	1.29E-06	1.11E-42
3.E-04	197	144	58	Ce-144	6.84E+03	4.3E-03	5.81E-07	5.79E-07
1.E-03	197	143	58	Ce-143	3.36E+01	5.6E-02	8.07E-05	4.92E-05
1.E-02	197	141	58	Ce-141	7.80E+02	6.3E-01	2.31E-04	2.26E-04
1.E-01	197	139	58	Ce-139	3.36E+03	3.0E+00	1.98E-03	1.97E-03
7.E-01	197	137	58	Ce-137	8.70E+00	3.8E+01	2.56E-03	3.79E-04
7.E-01	197	137	58	Ce-137	4.32E+01	3.8E+01	1.10E-01	7.49E-02
3.E+00	197	135	58	Ce-135	1.70E+01	1.5E+02	7.43E-03	2.80E-03
5.E+00	197	133	58	Ce-133	6.30E+00	2.8E+02	1.91E+00	1.37E-01
3.E+00	197	132	58	Ce-132	4.20E+00	1.8E+02	8.86E-01	1.70E-02
8.E-05	197	142	57	La-142	1.50E+00	4.8E-03	1.38E-05	2.15E-10
3.E-04	197	141	57	La-141	3.90E+00	1.9E-02	2.57E-06	3.63E-08
1.E-03	197	140	57	La-140	4.08E+01	7.1E-02	7.05E-04	4.69E-04
1.E-01	197	136	57	La-136	2.00E-01	7.2E+00	1.19E-02	1.03E-38
3.E-01	197	135	57	La-135	1.97E+01	1.9E+01	1.82E-03	7.82E-04
8.E-01	197	134	57	La-134	1.00E-01	4.4E+01	1.44E-01	1.07E-73
2.E+00	197	133	57	La-133	4.00E+00	9.1E+01	4.05E-01	6.36E-03
3.E+00	197	132	57	La-132	1.50E+00	1.6E+02	8.05E-01	1.25E-05
4.E+00	197	131	57	La-131	1.00E+00	2.4E+02	3.32E-01	2.03E-08

TABLE 3

Radioactivity Content And Exposure Rate From A 5 Cm Long Gold Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h
1.E-06	197	142	56	Ba-142	2.00E-01	7.2E-05	9.08E-09	7.84E-45
6.E-06	197	141	56	Ba-141	3.00E-01	3.4E-04	3.24E-08	2.94E-32
3.E-05	197	140	56	Ba-140	3.07E+02	1.5E-03	3.00E-06	2.84E-06
1.E-04	197	139	56	Ba-139	1.40E+00	6.2E-03	1.02E-06	7.22E-12
2.E-02	197	135	56	Ba-135	2.88E+01	1.1E+00	1.44E-04	8.09E-05
2.E-01	197	133	56	Ba-133	3.84E+01	9.0E+00	1.56E-03	1.01E-03
2.E-01	197	133	56	Ba-133	7.01E+04	2.9E-01	5.01E-04	5.01E-04
9.E-01	197	131	56	Ba-131	2.78E+02	5.1E+01	1.92E-01	1.81E-01
3.E+00	197	129	56	Ba-129	2.40E+00	1.7E+02	1.25E-01	1.23E-04
4.E+00	197	128	56	Ba-128	5.76E+01	2.2E+02	2.84E-01	2.13E-01
1.E+00	197	126	56	Ba-126	1.70E+00	7.5E+01	4.77E-01	2.73E-05
8.E-06	197	138	55	Cs-138	5.00E-01	4.5E-04	3.95E-06	1.48E-20
3.E-05	197	137	55	Cs-137	2.63E+05	1.8E-05	5.65E-08	5.65E-08
1.E-04	197	136	55	Cs-136	3.10E+02	8.3E-03	3.31E-05	3.14E-05
2.E-03	197	134	55	Cs-134	2.90E+00	1.2E-01	2.14E-05	6.98E-08
2.E-03	197	134	55	Cs-134	1.34E+04	2.0E-02	8.21E-05	8.20E-05
2.E-02	197	132	55	Cs-132	1.56E+02	1.4E+00	4.52E-03	4.06E-03
2.E-01	197	130	55	Cs-130	5.00E-01	1.1E+01	2.56E-02	9.61E-17
5.E-01	197	129	55	Cs-129	3.12E+01	2.7E+01	5.69E-02	3.34E-02
2.E+00	197	127	55	Cs-127	6.20E+00	1.1E+02	2.08E-01	1.43E-02
3.E+00	197	125	55	Cs-125	7.00E-01	1.6E+02	4.08E-01	2.03E-11
8.E-01	197	123	55	Cs-123	1.00E-01	4.5E+01	2.23E-01	1.66E-73
9.E-08	197	138	54	Xe-138	3.00E-01	5.2E-06	2.13E-09	1.93E-33
1.E-05	197	135	54	Xe-135	3.00E-01	6.2E-04	6.40E-07	5.80E-31
1.E-05	197	135	54	Xe-135	8.40E+00	6.2E-04	7.53E-07	1.04E-07
2.E-04	197	133	54	Xe-133	1.27E+02	1.1E-02	2.22E-06	1.95E-06
2.E-04	197	133	54	Xe-133	5.52E+01	1.1E-02	1.33E-06	9.85E-07
3.E-03	197	131	54	Xe-131	2.88E+02	1.7E-01	3.23E-06	3.05E-06
3.E-02	197	129	54	Xe-129	1.92E+02	1.8E+00	5.28E-05	4.85E-05
2.E-01	197	127	54	Xe-127	8.74E+02	1.3E+01	1.50E-02	1.47E-02
1.E+00	197	125	54	Xe-125	1.80E+01	6.8E+01	3.18E-02	1.26E-02
3.E+00	197	123	54	Xe-123	1.80E+00	1.6E+02	6.62E-01	6.51E-05
2.E+00	197	122	54	Xe-122	1.90E+01	1.1E+02	7.11E-02	2.97E-02
1.E+00	197	121	54	Xe-121	7.00E-01	6.0E+01	3.08E-01	1.53E-11
1.E-07	197	135	53	I-135	6.70E+00	7.4E-06	7.02E-08	5.89E-09
7.E-07	197	134	53	I-134	9.00E-01	3.8E-05	3.02E-07	2.93E-15
3.E-06	197	133	53	I-133	2.10E+01	1.9E-04	4.85E-07	2.20E-07
2.E-05	197	132	53	I-132	2.30E+00	8.7E-04	7.64E-06	5.59E-09
7.E-05	197	131	53	I-131	1.94E+02	3.9E-03	7.18E-06	6.59E-06
3.E-04	197	130	53	I-130	1.25E+01	1.6E-02	1.68E-04	4.45E-05
4.E-03	197	128	53	I-128	4.00E-01	2.3E-01	1.09E-04	1.01E-22
4.E-02	197	126	53	I-126	3.17E+02	2.4E+00	4.89E-03	4.64E-03
1.E-01	197	125	53	I-125	1.44E+03	5.5E+00	2.67E-04	2.64E-04
3.E-01	197	124	53	I-124	1.01E+02	1.8E+01	6.87E-02	5.83E-02
7.E-01	197	123	53	I-123	1.30E+01	4.0E+01	3.12E-02	8.70E-03
2.E+00	197	121	53	I-121	1.40E+00	1.2E+02	2.20E-01	1.55E-06
2.E+00	197	120	53	I-120	1.40E+00	1.3E+02	5.71E-01	4.03E-06
3.E-08	197	133	52	Te-133	1.00E+00	2.0E-06	4.16E-10	2.55E-17
2.E-07	197	132	52	Te-132	7.92E+01	1.1E-05	1.20E-08	9.76E-09
1.E-06	197	131	52	Te-131	4.00E-01	5.5E-05	3.84E-08	3.57E-26

TABLE 3

Radioactivity Content And Exposure Rate From A 5 Cm Long Gold Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h
1.E-06	197	131	52	Te-131	2.88E+01	5.5E-05	7.25E-08	4.07E-08
2.E-05	197	129	52	Te-129	1.10E+00	1.3E-03	1.35E-06	3.75E-13
2.E-05	197	129	52	Te-129	7.92E+02	1.2E-03	2.97E-06	2.90E-06
4.E-04	197	127	52	Te-127	9.40E+00	2.3E-02	4.49E-07	7.67E-08
4.E-04	197	127	52	Te-127	2.52E+03	1.4E-02	2.98E-06	2.96E-06
6.E-02	197	123	52	Te-123	2.50E+03	2.0E+00	6.53E-04	6.49E-04
4.E-01	197	121	52	Te-121	3.70E+03	1.0E+01	3.34E-02	3.33E-02
4.E-01	197	121	52	Te-121	4.08E+02	2.2E+01	3.14E-02	3.01E-02
1.E+00	197	119	52	Te-119	1.60E+01	8.6E+01	1.52E-01	5.37E-02
1.E+00	197	119	52	Te-119	1.13E+02	8.6E+01	2.86E-01	2.47E-01
2.E+00	197	117	52	Te-117	1.10E+00	8.9E+01	2.89E-01	8.01E-08
8.E-01	197	116	52	Te-116	2.50E+00	4.6E+01	4.85E-01	6.32E-04
3.E-07	197	129	51	Sb-129	4.30E+00	1.6E-05	2.53E-08	5.32E-10
1.E-06	197	128	51	Sb-128	9.00E+00	8.2E-05	2.13E-07	3.37E-08
1.E-06	197	128	51	Sb-128	2.00E-01	8.2E-05	1.47E-07	1.27E-43
7.E-06	197	127	51	Sb-127	9.36E+01	4.1E-04	1.79E-06	1.50E-06
3.E-05	197	126	51	Sb-126	3.00E-01	1.9E-03	4.02E-06	3.65E-30
3.E-05	197	126	51	Sb-126	3.00E+02	1.9E-03	1.64E-05	1.55E-05
6.E-04	197	124	51	Sb-124	1.44E+03	2.7E-02	1.96E-04	1.93E-04
8.E-03	197	122	51	Sb-122	6.72E+01	4.6E-01	1.00E-03	7.82E-04
8.E-02	197	120	51	Sb-120	1.39E+02	4.4E+00	2.62E-02	2.33E-02
2.E-01	197	119	51	Sb-119	3.84E+01	1.2E+01	2.06E-03	1.33E-03
5.E-01	197	118	51	Sb-118	5.10E+00	2.8E+01	1.52E-01	5.85E-03
1.E+00	197	117	51	Sb-117	2.80E+00	5.6E+01	5.06E-02	1.34E-04
2.E+00	197	116	51	Sb-116	3.00E-01	9.2E+01	5.11E-01	4.63E-25
2.E+00	197	116	51	Sb-116	1.00E+00	9.2E+01	4.14E-01	2.54E-08
4.E-07	197	126	50	Sn-126	8.76E+08	6.5E-11	3.44E-13	3.44E-13
2.E-06	197	125	50	Sn-125	2.00E-01	1.3E-04	2.17E-07	1.87E-43
2.E-06	197	125	50	Sn-125	2.26E+02	1.3E-04	3.55E-08	3.30E-08
5.E-05	197	123	50	Sn-123	3.00E+03	1.6E-03	7.54E-08	7.50E-08
5.E-05	197	123	50	Sn-123	7.00E-01	2.9E-03	2.26E-06	1.12E-16
9.E-04	197	121	50	Sn-121	2.19E+05	5.4E-04	1.41E-07	1.41E-07
1.E-02	197	119	50	Sn-119	6.00E+03	2.1E-01	4.57E-05	4.56E-05
1.E-01	197	117	50	Sn-117	3.36E+02	6.0E+00	2.34E-03	2.23E-03
2.E+00	197	113	50	Sn-113	2.83E+03	5.1E+01	1.62E-01	1.61E-01
6.E-01	197	111	50	Sn-111	6.00E-01	3.4E+01	4.92E-02	4.69E-14
2.E-01	197	110	50	Sn-110	4.00E+00	1.4E+01	1.45E-01	2.27E-03
8.E-02	197	109	50	Sn-109	3.00E-01	4.9E+00	6.96E-03	6.31E-27
5.E-03	197	117	49	In-117	7.00E-01	2.9E-01	4.96E-04	2.47E-14
5.E-03	197	117	49	In-117	1.90E+00	2.9E-01	1.59E-04	2.54E-08
2.E-02	197	116	49	In-116	9.00E-01	9.8E-01	5.90E-03	5.72E-11
5.E-02	197	115	49	In-115	4.50E+00	3.0E+00	2.26E-03	5.65E-05
1.E-01	197	114	49	In-114	1.20E+03	7.1E+00	1.30E-03	1.28E-03
3.E-01	197	113	49	In-113	1.70E+00	2.0E+01	1.25E-02	7.16E-07
7.E-01	197	112	49	In-112	4.00E-01	4.1E+01	1.55E-02	1.44E-20
7.E-01	197	112	49	In-112	2.00E-01	4.1E+01	2.98E-02	2.57E-38
1.E+00	197	111	49	In-111	6.72E+01	6.9E+01	1.35E-01	1.06E-01
1.E+00	197	110	49	In-110	4.90E+00	7.3E+01	7.66E-01	2.58E-02
7.E-01	197	109	49	In-109	4.30E+00	4.2E+01	1.13E-01	2.38E-03
3.E-01	197	108	49	In-108	7.00E-01	1.9E+01	7.16E-02	3.56E-12

TABLE 3

Radioactivity Content And Exposure Rate From A 5 Cm Long Gold Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h
3.E-01	197	108	49	In-108	9.00E-01	1.9E+01	1.65E-01	1.59E-09
1.E-01	197	107	49	In-107	6.00E-01	7.0E+00	4.24E-02	4.03E-14
1.E-04	197	117	48	Cd-117	2.90E+00	7.2E-03	1.56E-05	5.10E-08
2.E-03	197	115	48	Cd-115	1.03E+03	1.1E-01	1.05E-05	1.03E-05
2.E-03	197	115	48	Cd-115	5.52E+01	1.2E-01	3.23E-04	2.39E-04
2.E-01	197	111	48	Cd-111	8.00E-01	1.1E+01	7.34E-03	7.07E-12
8.E-01	197	109	48	Cd-109	1.14E+04	8.9E+00	3.43E-04	3.42E-04
9.E-01	197	107	48	Cd-107	6.50E+00	5.0E+01	9.61E-04	7.46E-05
2.E-01	197	105	48	Cd-105	9.00E-01	9.7E+00	2.41E-02	2.33E-10
6.E-02	197	104	48	Cd-104	1.00E+00	3.2E+00	1.85E-03	1.13E-10
5.E-05	197	115	47	Ag-115	4.00E-01	2.6E-03	3.03E-07	2.82E-25
9.E-04	197	113	47	Ag-113	5.30E+00	4.9E-02	3.63E-05	1.58E-06
3.E-03	197	112	47	Ag-112	3.20E+00	1.9E-01	3.58E-04	2.00E-06
1.E-02	197	111	47	Ag-111	1.80E+02	6.7E-01	9.06E-05	8.26E-05
4.E-02	197	110	47	Ag-110	6.07E+03	6.8E-01	3.88E-03	3.87E-03
9.E-01	197	106	47	Ag-106	1.99E+02	5.3E+01	2.20E-01	2.03E-01
9.E-01	197	105	47	Ag-105	9.60E+02	5.0E+01	2.07E-01	2.03E-01
5.E-01	197	104	47	Ag-104	1.20E+00	3.0E+01	1.22E-01	1.19E-07
2.E-01	197	103	47	Ag-103	1.10E+00	1.3E+01	3.12E-02	8.66E-09
8.E-05	197	112	46	Pd-112	2.10E+01	4.4E-03	1.79E-06	8.12E-07
3.E-04	197	111	46	Pd-111	5.50E+00	2.0E-02	3.19E-05	1.55E-06
3.E-04	197	111	46	Pd-111	4.00E-01	2.0E-02	3.79E-06	3.52E-24
5.E-03	197	109	46	Pd-109	1.35E+01	3.0E-01	1.17E-05	3.42E-06
9.E-01	197	103	46	Pd-103	4.08E+02	5.3E+01	3.33E-02	3.19E-02
3.E-01	197	101	46	Pd-101	8.50E+00	1.7E+01	2.17E-02	3.08E-03
1.E-01	197	100	46	Pd-100	9.84E+01	6.4E+00	2.79E-03	2.36E-03
3.E-02	197	99	46	Pd-99	4.00E-01	2.0E+00	2.60E-02	2.41E-20
2.E-03	197	107	45	Rh-107	4.00E-01	1.3E-01	1.81E-04	1.68E-22
8.E-03	197	106	45	Rh-106	2.20E+00	4.8E-01	2.35E-03	1.24E-06
3.E-02	197	105	45	Rh-105	3.60E+01	1.6E+00	2.45E-04	1.55E-04
2.E-01	197	103	45	Rh-103	1.00E+00	1.2E+01	2.59E-03	1.58E-10
4.E-01	197	102	45	Rh-102	4.94E+03	9.3E+00	4.26E-02	4.24E-02
7.E-01	197	101	45	Rh-101	4.38E+04	2.1E+00	1.68E-03	1.68E-03
7.E-01	197	101	45	Rh-101	1.08E+02	4.1E+01	3.13E-02	2.68E-02
7.E-01	197	100	45	Rh-100	2.10E+01	4.0E+01	3.15E-01	1.43E-01
4.E-01	197	99	45	Rh-99	4.70E+00	2.1E+01	1.74E-02	5.09E-04
4.E-01	197	99	45	Rh-99	3.84E+02	2.1E+01	7.44E-02	7.13E-02
1.E-01	197	98	45	Rh-98	1.00E-01	8.6E+00	7.00E-02	5.22E-74
1.E-03	197	105	44	Ru-105	4.40E+00	5.7E-02	2.15E-04	4.93E-06
1.E-02	197	103	44	Ru-103	9.60E+02	7.1E-01	1.71E-03	1.69E-03
4.E-01	197	97	44	Ru-97	6.96E+01	2.5E+01	4.56E-03	3.60E-03
7.E-02	197	95	44	Ru-95	1.70E+00	4.0E+00	8.85E-03	5.06E-07
9.E-05	197	104	43	Tc-104	3.00E-01	5.2E-03	3.95E-06	3.58E-30
6.E-03	197	101	43	Tc-101	2.00E-01	3.7E-01	5.60E-04	4.83E-40
6.E-02	197	99	43	Tc-99	6.00E+00	3.7E+00	1.15E-03	7.20E-05
2.E-01	197	98	43	Tc-98	1.31E+10	1.7E-06	1.15E-08	1.15E-08
3.E-01	197	97	43	Tc-97	2.18E+03	1.3E+01	6.37E-04	6.32E-04
6.E-01	197	96	43	Tc-96	9.00E-01	3.3E+01	1.05E-02	1.02E-10
6.E-01	197	96	43	Tc-96	1.03E+02	3.3E+01	3.96E-01	3.37E-01
5.E-01	197	95	43	Tc-95	2.00E+01	2.8E+01	5.29E-02	2.31E-02

TABLE 3

Radioactivity Content And Exposure Rate From A 5 Cm Long Gold Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h
5.E-01	197	95	43	Tc-95	1.44E+03	2.2E+01	2.12E-02	2.10E-02
2.E-01	197	94	43	Tc-94	9.00E-01	1.4E+01	1.42E-01	1.37E-09
9.E-02	197	93	43	Tc-93	2.70E+00	5.3E+00	2.39E-02	5.08E-05
2.E-04	197	101	42	Mo-101	3.00E-01	9.7E-03	3.36E-05	3.05E-29
3.E-03	197	99	42	Mo-99	6.72E+01	1.7E-01	2.07E-04	1.61E-04
5.E-01	197	93	42	Mo-93	6.90E+00	2.9E+01	1.61E-01	1.45E-02
1.E-01	197	91	42	Mo-91	3.00E-01	6.9E+00	3.45E-02	3.13E-26
4.E-02	197	90	42	Mo-90	6.00E+00	2.3E+00	1.24E-02	7.79E-04
1.E-03	197	97	41	Nb-97	1.20E+00	7.8E-02	2.55E-04	2.49E-10
5.E-03	197	96	41	Nb-96	2.30E+01	3.0E-01	3.31E-03	1.61E-03
2.E-02	197	95	41	Nb-95	8.40E+02	9.7E-01	3.67E-03	3.60E-03
2.E-02	197	95	41	Nb-95	9.12E+01	1.0E+00	1.21E-04	1.01E-04
5.E-02	197	94	41	Nb-94	1.00E-01	3.1E+00	6.36E-04	4.74E-76
5.E-02	197	94	41	Nb-94	2.10E+08	3.5E-05	2.66E-07	2.66E-07
1.E-01	197	93	41	Nb-93	3.24E+04	5.6E-01	4.30E-05	4.30E-05
3.E-01	197	92	41	Nb-92	2.42E+02	1.7E+01	7.87E-02	7.35E-02
5.E-01	197	91	41	Nb-91	1.44E+03	2.1E+01	5.24E-02	5.18E-02
3.E-01	197	90	41	Nb-90	1.46E+01	1.9E+01	3.76E-01	1.20E-01
2.E-01	197	89	41	Nb-89	1.90E+00	8.7E+00	1.96E-02	3.13E-06
2.E-01	197	89	41	Nb-89	1.00E+00	8.7E+00	1.26E-02	7.70E-10
3.E-05	197	97	40	Zr-97	1.70E+01	1.5E-03	8.42E-07	3.17E-07
6.E-04	197	95	40	Zr-95	1.56E+03	2.7E-02	9.47E-05	9.37E-05
3.E-01	197	89	40	Zr-89	9.12E+01	2.0E+01	2.68E-02	2.23E-02
4.E-01	197	88	40	Zr-88	2.04E+03	1.4E+01	2.67E-02	2.64E-02
2.E-01	197	87	40	Zr-87	1.70E+00	1.1E+01	5.00E-02	2.86E-06
7.E-02	197	86	40	Zr-86	1.70E+01	4.1E+00	1.05E-01	3.95E-02
5.E-05	197	94	39	Y-94	3.00E-01	3.0E-03	7.23E-06	6.55E-30
3.E-04	197	93	39	Y-93	1.01E+01	1.5E-02	8.79E-06	1.70E-06
1.E-03	197	92	39	Y-92	3.50E+00	6.6E-02	4.21E-05	3.66E-07
5.E-03	197	91	39	Y-91	8.00E-01	2.6E-01	3.52E-04	3.39E-13
2.E-02	197	90	39	Y-90	3.10E+00	9.2E-01	4.43E-04	2.09E-06
1.E-01	197	88	39	Y-88	2.59E+03	4.2E+00	5.44E-02	5.40E-02
3.E-01	197	87	39	Y-87	1.40E+01	1.4E+01	1.08E-02	3.29E-03
3.E-01	197	87	39	Y-87	7.92E+01	1.4E+01	3.39E-02	2.75E-02
4.E-01	197	86	39	Y-86	1.46E+01	2.1E+01	2.66E-01	8.53E-02
2.E-01	197	85	39	Y-85	2.70E+00	1.2E+01	7.62E-02	1.62E-04
9.E-02	197	84	39	Y-84	3.70E+00	5.1E+00	2.56E-02	2.88E-04
2.E-05	197	92	38	Sr-92	2.70E+00	1.2E-03	7.47E-06	1.59E-08
1.E-04	197	91	38	Sr-91	9.70E+00	6.3E-03	3.28E-05	5.92E-06
3.E-02	197	87	38	Sr-87	2.90E+00	1.6E+00	1.19E-03	3.89E-06
2.E-01	197	85	38	Sr-85	1.20E+00	9.9E+00	5.74E-03	5.60E-09
2.E-01	197	85	38	Sr-85	1.54E+03	7.7E+00	1.92E-02	1.90E-02
2.E-01	197	83	38	Sr-83	3.36E+01	1.4E+01	1.04E-01	6.36E-02
4.E-05	197	89	37	Rb-89	2.00E-01	2.6E-03	2.89E-05	2.49E-41
2.E-04	197	88	37	Rb-88	3.00E-01	1.3E-02	9.21E-05	8.35E-29
4.E-03	197	86	37	Rb-86	4.49E+02	2.4E-01	1.14E-04	1.10E-04
4.E-02	197	84	37	Rb-84	7.92E+02	2.5E+00	1.00E-02	9.82E-03
1.E-01	197	83	37	Rb-83	1.99E+03	4.5E+00	1.13E-02	1.12E-02
2.E-01	197	82	37	Rb-82	6.30E+00	1.3E+01	8.80E-02	6.30E-03
3.E-01	197	81	37	Rb-81	4.70E+00	1.4E+01	2.77E-02	8.09E-04

TABLE 3

Radioactivity Content And Exposure Rate From A 5 Cm Long Gold Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h
5.E-02	197	79	37	Rb-79	4.00E-01	2.8E+00	1.45E-02	1.34E-20
3.E-06	197	88	36	Kr-88	2.80E+00	1.8E-04	1.64E-06	4.36E-09
2.E-05	197	87	36	Kr-87	1.30E+00	1.0E-03	2.85E-06	8.08E-12
5.E-04	197	85	36	Kr-85	4.40E+00	2.7E-02	1.22E-05	2.81E-07
5.E-04	197	85	36	Kr-85	9.37E+04	6.7E-04	6.53E-09	6.52E-09
8.E-03	197	83	36	Kr-83	1.90E+00	4.6E-01	1.85E-04	2.96E-08
2.E-01	197	79	36	Kr-79	3.36E+01	1.4E+01	9.92E-03	6.05E-03
6.E-02	197	77	36	Kr-77	1.20E+00	3.5E+00	1.73E-02	1.69E-08
2.E-02	197	76	36	Kr-76	1.48E+01	1.1E+00	1.44E-03	4.70E-04
4.E-05	197	84	35	Br-84	1.00E-01	2.4E-03	2.49E-05	1.85E-77
4.E-05	197	84	35	Br-84	5.00E-01	2.4E-03	5.19E-06	1.95E-20
2.E-04	197	83	35	Br-83	2.40E+00	1.2E-02	3.60E-07	3.56E-10
1.E-03	197	82	35	Br-82	3.60E+01	5.8E-02	7.39E-04	4.66E-04
1.E-02	197	80	35	Br-80	3.00E-01	8.4E-01	1.06E-04	9.60E-29
1.E-02	197	80	35	Br-80	4.40E+00	8.4E-01	8.96E-05	2.06E-06
1.E-01	197	78	35	Br-78	1.00E-01	6.1E+00	3.05E-02	2.28E-74
2.E-01	197	77	35	Br-77	5.76E+01	1.1E+01	4.24E-02	3.18E-02
2.E-01	197	76	35	Br-76	1.70E+01	9.4E+00	4.03E-02	1.52E-02
7.E-02	197	75	35	Br-75	1.70E+00	4.2E+00	2.85E-02	1.63E-06
2.E-02	197	74	35	Br-74	6.00E-01	1.4E+00	1.07E-02	1.02E-14
3.E-06	197	83	34	Se-83	4.00E-01	1.6E-04	5.53E-07	5.14E-25
1.E-01	197	75	34	Se-75	2.88E+03	4.6E+00	1.47E-02	1.46E-02
9.E-02	197	73	34	Se-73	7.10E+00	5.0E+00	1.31E-02	1.26E-03
3.E-02	197	72	34	Se-72	2.02E+02	1.8E+00	3.62E-04	3.33E-04
8.E-03	197	71	34	Se-71	1.00E-01	4.9E-01	2.63E-03	1.96E-75
2.E-03	197	70	34	Se-70	7.00E-01	1.1E-01	5.35E-04	2.66E-14
4.E-05	197	79	33	As-79	1.00E-01	2.4E-03	1.10E-06	8.20E-79
2.E-04	197	78	33	As-78	1.50E+00	1.3E-02	1.91E-05	2.96E-10
1.E-03	197	77	33	As-77	3.84E+01	6.0E-02	3.47E-06	2.25E-06
4.E-03	197	76	33	As-76	2.64E+01	2.5E-01	5.13E-04	2.73E-04
4.E-02	197	74	33	As-74	4.25E+02	2.6E+00	9.07E-03	8.72E-03
1.E-01	197	73	33	As-73	1.82E+03	4.3E+00	1.69E-02	1.68E-02
2.E-01	197	72	33	As-72	2.64E+01	9.4E+00	7.94E-02	4.23E-02
1.E-01	197	71	33	As-71	6.24E+01	5.6E+00	1.39E-02	1.06E-02
4.E-02	197	70	33	As-70	8.00E-01	2.2E+00	3.54E-02	3.41E-11
1.E-02	197	69	33	As-69	2.00E-01	6.3E-01	3.88E-03	3.35E-39
3.E-03	197	68	33	As-68	1.00E-01	1.5E-01	7.23E-04	5.39E-76
2.E-05	197	77	32	Ge-77	1.13E+01	1.0E-03	1.83E-06	4.22E-07
5.E-04	197	75	32	Ge-75	1.40E+00	2.9E-02	5.35E-06	3.77E-11
1.E-01	197	69	32	Ge-69	4.08E+01	6.2E+00	4.77E-02	3.18E-02
1.E-02	197	67	32	Ge-67	3.00E-01	8.1E-01	4.04E-03	3.66E-27
3.E-03	197	66	32	Ge-66	2.40E+00	1.9E-01	1.20E-03	1.19E-06
4.E-05	197	74	31	Ga-74	1.00E-01	2.5E-03	2.26E-05	1.68E-77
2.E-04	197	73	31	Ga-73	4.80E+00	1.4E-02	2.03E-05	6.37E-07
1.E-03	197	72	31	Ga-72	1.41E+01	6.7E-02	4.30E-04	1.32E-04
2.E-02	197	70	31	Ga-70	4.00E-01	9.6E-01	4.63E-05	4.30E-23
1.E-01	197	68	31	Ga-68	1.10E+00	5.7E+00	2.56E-02	7.10E-09
1.E-01	197	67	31	Ga-67	7.92E+01	6.5E+00	8.49E-03	6.89E-03
5.E-02	197	66	31	Ga-66	9.50E+00	3.1E+00	2.34E-02	4.08E-03
2.E-02	197	65	31	Ga-65	2.00E-01	1.0E+00	6.85E-03	5.91E-39

TABLE 3

Radioactivity Content And Exposure Rate From A 5 Cm Long Gold Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h
2.E-05	197	72	30	Zn-72	4.56E+01	1.1E-03	7.61E-07	5.28E-07
1.E-04	197	71	30	Zn-71	4.00E+00	6.5E-03	4.68E-05	7.36E-07
3.E-03	197	69	30	Zn-69	1.39E+01	1.5E-01	1.60E-04	4.85E-05
1.E-01	197	65	30	Zn-65	5.88E+03	2.1E+00	5.65E-03	5.64E-03
2.E-02	197	63	30	Zn-63	6.00E-01	1.2E+00	5.03E-03	4.79E-15
6.E-03	197	62	30	Zn-62	9.30E+00	3.2E-01	4.55E-04	7.63E-05
1.E-03	197	67	29	Cu-67	6.00E+01	7.9E-02	6.20E-05	4.70E-05
6.E-03	197	66	29	Cu-66	1.00E-01	3.2E-01	1.47E-04	1.10E-76
5.E-02	197	64	29	Cu-64	1.28E+01	2.9E+00	2.93E-03	8.00E-04
7.E-02	197	62	29	Cu-62	2.00E-01	3.8E+00	1.87E-02	1.61E-38
3.E-02	197	61	29	Cu-61	3.30E+00	1.5E+00	5.99E-03	3.91E-05
7.E-03	197	60	29	Cu-60	4.00E-01	4.0E-01	4.34E-03	4.03E-21
7.E-04	197	65	28	Ni-65	2.50E+00	4.1E-02	1.18E-04	1.53E-07
2.E-03	197	57	28	Ni-57	3.60E+01	1.1E-01	1.04E-03	6.54E-04
3.E-04	197	56	28	Ni-56	1.46E+02	1.8E-02	1.36E-04	1.21E-04
2.E-03	197	62	27	Co-62	2.00E-01	1.0E-01	1.40E-03	1.21E-39
7.E-03	197	61	27	Co-61	1.70E+00	4.0E-01	1.40E-04	8.00E-09
2.E-02	197	60	27	Co-60	4.64E+04	6.3E-02	7.70E-04	7.69E-04
2.E-02	197	60	27	Co-60	2.00E-01	1.3E+00	3.98E-04	3.44E-40
7.E-02	197	58	27	Co-58	9.00E+00	4.1E+00	2.37E-03	3.74E-04
7.E-02	197	58	27	Co-58	1.70E+03	3.0E+00	1.43E-02	1.42E-02
3.E-02	197	57	27	Co-57	6.41E+03	5.9E-01	3.47E-04	3.46E-04
1.E-02	197	56	27	Co-56	1.85E+03	4.3E-01	5.35E-03	5.31E-03
2.E-03	197	55	27	Co-55	1.80E+01	1.4E-01	1.20E-03	4.75E-04
9.E-04	197	60	26	Fe-60	8.76E+08	1.4E-07	1.44E-10	1.44E-10
4.E-03	197	59	26	Fe-59	1.08E+03	2.1E-01	1.21E-03	1.19E-03
3.E-03	197	53	26	Fe-53	1.00E-01	1.7E-01	8.37E-04	6.24E-76
5.E-04	197	52	26	Fe-52	8.30E+00	3.0E-02	1.05E-04	1.42E-05
9.E-03	197	56	25	Mn-56	2.60E+00	5.2E-01	4.62E-03	7.76E-06
5.E-02	197	54	25	Mn-54	7.54E+03	8.3E-01	3.39E-03	3.39E-03
1.E-02	197	52	25	Mn-52	4.00E-01	8.3E-01	9.67E-03	8.99E-21
1.E-02	197	52	25	Mn-52	1.37E+02	8.3E-01	7.06E-03	6.25E-03
4.E-03	197	51	25	Mn-51	7.00E-01	2.0E-01	1.02E-03	5.07E-14
4.E-02	197	51	24	Cr-51	6.67E+02	2.3E+00	3.63E-04	3.54E-04
4.E-03	197	49	24	Cr-49	7.00E-01	2.5E-01	9.60E-04	4.77E-14
8.E-04	197	48	24	V-48	2.30E+01	4.6E-02	9.55E-05	4.64E-05
2.E-02	197	48	23	V-48	3.89E+02	1.1E+00	1.51E-02	1.45E-02
5.E-03	197	47	23	V-47	5.00E-01	2.9E-01	1.45E-03	5.43E-18
4.E-04	197	51	22	Ti-51	1.00E-01	2.3E-02	3.90E-05	2.91E-77
6.E-03	197	45	22	Ti-45	3.10E+00	3.4E-01	1.41E-03	6.62E-06
1.E-03	197	44	22	Ti-44	8.76E+06	1.8E-05	1.15E-08	1.15E-08
1.E-03	197	48	21	Sc-48	4.32E+01	6.6E-02	1.07E-03	7.31E-04
5.E-03	197	47	21	Sc-47	8.16E+01	2.9E-01	1.58E-04	1.29E-04
2.E-02	197	46	21	Sc-46	2.02E+03	6.3E-01	6.22E-03	6.17E-03
2.E-02	197	44	21	Sc-44	5.76E+01	1.3E+00	8.24E-04	6.18E-04
7.E-03	197	43	21	Sc-43	3.90E+00	3.9E-01	1.89E-03	2.67E-05
2.E-06	197	49	20	Ca-49	1.00E-01	1.0E-04	1.64E-06	1.22E-78
1.E-04	197	47	20	Ca-47	1.13E+02	6.3E-03	3.05E-05	2.64E-05
4.E-04	197	44	19	K-44	4.00E-01	2.1E-02	1.42E-04	1.32E-22
2.E-03	197	43	19	K-43	2.20E+01	1.1E-01	5.05E-04	2.37E-04

TABLE 3

Radioactivity Content And Exposure Rate From A 5 Cm Long Gold Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h
7.E-03	197	42	19	K-42	1.24E+01	4.3E-01	5.76E-04	1.51E-04
2.E-03	197	38	19	K-38	1.00E-01	1.1E-01	1.62E-03	1.21E-75
1.E-03	197	41	18	Ar-41	1.80E+00	6.5E-02	4.05E-04	3.99E-08
7.E-04	197	39	17	Cl-39	9.00E-01	3.8E-02	1.80E-04	1.75E-12
3.E-03	197	38	17	Cl-38	6.00E-01	1.9E-01	1.36E-03	1.30E-15
2.E-03	197	34	17	Cl-34	6.00E-01	1.4E-01	5.28E-04	5.02E-16
5.E-05	197	38	16	S-38	2.90E+00	3.1E-03	2.73E-05	8.89E-08
4.E-04	197	37	16	S-37	1.00E-01	2.2E-02	3.29E-05	2.45E-77
3.E-03	197	29	13	Al-29	1.00E-01	1.4E-01	9.60E-04	7.16E-76
3.E-03	197	26	13	Al-26	6.13E+09	7.2E-08	9.48E-10	9.48E-10
3.E-04	197	28	12	Mg-28	2.12E+01	1.5E-02	9.27E-05	4.24E-05
2.E-03	197	27	12	Mg-27	2.00E-01	9.5E-02	4.08E-04	3.52E-40
5.E-03	197	24	11	Na-24	1.50E+01	2.8E-01	5.57E-03	1.84E-03
4.E-03	197	22	11	Na-22	2.28E+04	2.0E-02	2.16E-04	2.16E-04
4.E-03	197	18	9	F-18	1.80E+00	2.2E-01	1.03E-03	1.02E-07
5.E-04	197	13	7	N-13	2.00E-01	3.1E-02	1.57E-04	1.35E-40
5.E-04	197	11	6	C-11	3.00E-01	2.9E-02	1.47E-04	1.33E-28
4.E-04	197	7	4	Be-7	1.28E+03	1.9E-02	5.37E-06	5.30E-06
Sum 1.9E+03						Sum 1.0E+05	Sum 2.15E+02	Sum 7.73E+01

TABLE 4

Radioactivity Content And Exposure Rate From An 8.9 Cm Long Copper Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (Rudstam Formula) σ, mb	Mass of Target Nucleus (63.54 Equals All Stable Isotopes of Cu)	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
1.E+01	63.54	63	30	Zn-63	6.00E-01	1.4E+03	5.70E+00	5.43E-12	4.92E-36
3.E+00	63.54	62	30	Zn-62	9.30E+00	3.6E+02	5.16E-01	8.65E-02	2.43E-03
2.E+01	63.54	64	29	Cu-64	1.28E+01	3.3E+03	3.32E+00	9.06E-01	6.77E-02
3.E+01	63.54	62	29	Cu-62	2.00E-01	4.3E+03	2.12E+01	1.83E-35	1.36E-107
1.E+01	63.54	61	29	Cu-61	3.30E+00	1.7E+03	6.79E+00	4.43E-02	1.88E-06
3.E+00	63.54	60	29	Cu-60	4.00E-01	4.6E+02	4.92E+00	4.57E-18	3.95E-54
3.E-01	63.54	65	28	Ni-65	2.50E+00	4.7E+01	1.33E-01	1.74E-04	2.95E-10
9.E-01	63.54	57	28	Ni-57	3.60E+01	1.2E+02	1.18E+00	7.41E-01	2.95E-01
2.E-01	63.54	56	28	Ni-56	1.46E+02	2.1E+01	1.54E-01	1.37E-01	1.09E-01
8.E-01	63.54	62	27	Co-62	2.00E-01	1.1E+02	1.58E+00	1.37E-36	1.02E-108
3.E+00	63.54	61	27	Co-61	1.70E+00	4.6E+02	1.59E-01	9.07E-06	2.96E-14
1.E+01	63.54	60	27	Co-60	4.64E+04	7.1E+01	8.72E-01	8.72E-01	8.72E-01
1.E+01	63.54	60	27	Co-60	2.00E-01	1.5E+03	4.52E-01	3.90E-37	2.91E-109
3.E+01	63.54	58	27	Co-58	9.00E+00	4.6E+03	2.68E+00	4.24E-01	1.06E-02
3.E+01	63.54	58	27	Co-58	1.70E+03	3.4E+03	1.62E+01	1.60E+01	1.57E+01
2.E+01	63.54	57	27	Co-57	6.41E+03	6.7E+02	3.94E-01	3.93E-01	3.91E-01
5.E+00	63.54	56	27	Co-56	1.85E+03	4.9E+02	6.07E+00	6.01E+00	5.91E+00
1.E+00	63.54	55	27	Co-55	1.80E+01	1.5E+02	1.35E+00	5.38E-01	8.50E-02
5.E-01	63.54	60	26	Fe-60	8.76E+08	1.6E-04	1.63E-07	1.63E-07	1.63E-07
2.E+00	63.54	59	26	Fe-59	1.08E+03	2.4E+02	1.37E+00	1.35E+00	1.31E+00
1.E+00	63.54	53	26	Fe-53	1.00E-01	1.9E+02	9.48E-01	7.07E-73	3.93E-217
2.E-01	63.54	52	26	Fe-52	8.30E+00	3.4E+01	1.19E-01	1.61E-02	2.95E-04
4.E+00	63.54	56	25	Mn-56	2.60E+00	5.9E+02	5.23E+00	8.80E-03	2.49E-08
3.E+01	63.54	54	25	Mn-54	7.54E+03	9.4E+02	3.85E+00	3.84E+00	3.82E+00
7.E+00	63.54	52	25	Mn-52	4.00E-01	9.4E+02	1.10E+01	1.02E-17	8.80E-54
7.E+00	63.54	52	25	Mn-52	1.37E+02	9.4E+02	8.00E+00	7.09E+00	5.56E+00
2.E+00	63.54	51	25	Mn-51	7.00E-01	2.3E+02	1.16E+00	5.74E-11	1.42E-31
2.E+01	63.54	51	24	Cr-51	6.67E+02	2.7E+03	4.11E-01	4.01E-01	3.82E-01
2.E+00	63.54	49	24	Cr-49	7.00E-01	2.8E+02	1.09E+00	5.41E-11	1.33E-31
4.E-01	63.54	48	24	V-48	2.30E+01	5.2E+01	1.08E-01	5.26E-02	1.24E-02
9.E+00	63.54	48	23	V-48	3.89E+02	1.2E+03	1.71E+01	1.64E+01	1.51E+01
2.E+00	63.54	47	23	V-47	5.00E-01	3.3E+02	1.64E+00	6.16E-15	8.67E-44
2.E-01	63.54	51	22	Ti-51	1.00E-01	2.6E+01	4.42E-02	3.30E-74	1.83E-218
3.E+00	63.54	45	22	Ti-45	3.10E+00	3.8E+02	1.59E+00	7.51E-03	1.67E-07
6.E-01	63.54	44	22	Ti-44	8.76E+06	2.0E-02	1.31E-05	1.31E-05	1.31E-05
5.E-01	63.54	48	21	Sc-48	4.32E+01	7.5E+01	1.22E+00	8.29E-01	3.84E-01
2.E+00	63.54	47	21	Sc-47	8.16E+01	3.2E+02	1.79E-01	1.46E-01	9.70E-02
8.E+00	63.54	46	21	Sc-46	2.02E+03	7.2E+02	7.05E+00	6.99E+00	6.88E+00
1.E+01	63.54	44	21	Sc-44	5.76E+01	1.4E+03	9.34E-01	7.00E-01	3.93E-01
3.E+00	63.54	43	21	Sc-43	3.90E+00	4.4E+02	2.14E+00	3.02E-02	6.05E-06
9.E-04	63.54	49	20	Ca-49	1.00E-01	1.2E-01	1.86E-03	1.39E-75	7.71E-220
5.E-02	63.54	47	20	Ca-47	1.13E+02	7.1E+00	3.46E-02	2.99E-02	2.22E-02
2.E-01	63.54	44	19	K-44	4.00E-01	2.4E+01	1.61E-01	1.50E-19	1.29E-55
9.E-01	63.54	43	19	K-43	2.20E+01	1.2E+02	5.73E-01	2.69E-01	5.95E-02
4.E+00	63.54	42	19	K-42	1.24E+01	4.9E+02	6.53E-01	1.71E-01	1.17E-02
9.E-01	63.54	38	19	K-38	1.00E-01	1.2E+02	1.84E+00	1.37E-72	7.60E-217
5.E-01	63.54	41	18	Ar-41	1.80E+00	7.4E+01	4.59E-01	4.52E-05	4.37E-13
3.E-01	63.54	39	17	Cl-39	9.00E-01	4.3E+01	2.04E-01	1.98E-09	1.85E-25

TABLE 4

Radioactivity Content And Exposure Rate From An 8.9 Cm Long Copper Target Hit With High Intensity Proton Beam (20 TPP, 3 Second Rep Rate)

Inelastic Cross Section (*Rudstam* Formula) σ, mb	*Mass of* Target Nucleus (*63.54* Equals All Stable Isotopes of Cu)	*Mass of* Product Nucleus	*Proton* Number of Product *Nucleus*	Nuclide	*Half-life, h*	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h	Exposure Rate at One Foot After 72 Hours Decay, R/h
2.E+00	63.54	38	17	Cl-38	6.00E-01	2.1E+02	1.54E+00	1.47E-12	1.33E-36
1.E+00	63.54	34	17	Cl-34	6.00E-01	1.5E+02	5.98E-01	5.70E-13	5.16E-37
3.E-02	63.54	38	16	S-38	2.90E+00	3.5E+00	3.09E-02	1.01E-04	1.07E-09
2.E-01	63.54	37	16	S-37	1.00E-01	2.5E+01	3.73E-02	2.78E-74	1.55E-218
1.E+00	63.54	29	13	Al-29	1.00E-01	1.6E+02	1.09E+00	8.11E-73	4.51E-217
2.E+00	63.54	26	13	Al-26	6.13E+09	8.1E-05	1.07E-06	1.07E-06	1.07E-06
1.E-01	63.54	28	12	Mg-28	2.12E+01	1.7E+01	1.05E-01	4.80E-02	1.00E-02
8.E-01	63.54	27	12	Mg-27	2.00E-01	1.1E+02	4.63E-01	3.99E-37	2.98E-109
2.E+00	63.54	24	11	Na-24	1.50E+01	3.1E+02	6.31E+00	2.09E+00	2.28E-01
2.E+00	63.54	22	11	Na-22	2.28E+04	2.3E+01	2.44E-01	2.44E-01	2.44E-01
2.E+00	63.54	18	9	F-18	1.80E+00	2.5E+02	1.17E+00	1.15E-04	1.12E-12
3.E-01	63.54	13	7	N-13	2.00E-01	3.6E+01	1.77E-01	1.53E-37	1.14E-109
2.E-01	63.54	11	6	C-11	3.00E-01	3.3E+01	1.67E-01	1.51E-25	1.24E-73
2.E-01	63.54	7	4	Be-7	1.28E+03	2.2E+01	6.09E-03	6.01E-03	5.86E-03
Sum						Sum	Sum	Sum	Sum
3.3E+02						3.7E+04	1.55E+02	6.69E+01	5.79E+01

Neutron Activation

In addition to spallation produced radioactivity, neutrons boiled off in the spallation process would in turn be absorbed in the target. An estimate of the number of neutrons produced is from 1 to 4 times the proton population.[2] Table 5 was based on an assumption of equal amounts of neutrons and protons. With the exception of Au targets, no significant radioactivity is added by this absorption process after a 24 hour decay.

TABLE 5 Thermal Neutron Activation of Targets

Target Nuclide (% Abundance)	Thermal Neutron Cross Section, millibarns	Product Nuclide	Halflife, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Exposure Rate at One Foot, R/h	Exposure Rate at One Foot After 24 Hours Decay, R/h
Pt-190 (0.0127)	3160	Pt-191	7.20E+01	2.4E+01	5.47E-02	4.34E-02
Pt-192 (0.78)	2000	Pt-193 (no γ)	4.38E+06			
Pt-194 (32.9)	90	Pt-195m	9.84E+01	1.7E+03	4.21E-01	3.55E-01
Pt-195 (33.8)	27,000	Pt-196	Stable			
Pt-196 (25.3)	0					
Pt-198 (7.21)	30	Pt-199	5.17E-01	1.2E+02		
		Au-199	7.56E+01	1.2E+02	6.85E-02	5.50E-02
Au-197 (100)	98,800	Au-198	6.48E+01	5.7E+06	1.17E+04	9.07E+03
Ni-58 (67.88)	4400	Ni-59 (no γ)	7.01E+08			
Ni-60 (26.23)	2600	Ni-61	Stable			
Ni-61 (1.19)	2000	Ni-62	Stable			
Ni-62 (3.66)	15,000	Ni-63 (no γ)	8.06E+05			
Ni-64 (1.08)	1500	Ni-65	2.56E+00	1.1E+04	3.15E+01	4.80E-02
Cu-63 (69.09)	4500	Cu-64	8.50E-02	4.2E+05	4.31E+02	6.00E-83
Cu-65 (30.91)	2300	Cu-66	1.29E+01	9.4E+04	4.27E+01	1.18E+01

B5 Target Experience

On March 27, 1995, a low-background gamma survey was being performed on equipment near the B Test Beam Area. The owners, who are called AGS Users, planned to return this equipment to their university. The measurements showed that levels on the equipment were about 20 μR/h which was about twice background.

Ten days prior to this, on March 17, 1995, the B5 target broke during a high-intensity run (25 TP) and the failure was thought to be due to repeated thermo-mechanical stresses from the pulsed beam. Following the target break, it was discovered that the gate leading to B5 target was contaminated with beta emitters at about 80,000 dpm/100 cm^2, but the nearby B Test Beam Area was found to be clean. The levels outside this gate had been 200 to 1000 dpm/100 cm^2 routinely due to deposition of short-half-life (20 to 30 minutes)

[2] A. H. Sullivan, A Guide to Radiation and Radioactivity Levels Near High Energy Particle Accelerators, Nuclear Technology Publishing, Ashford, Kent England, TN23 1JW, 1992.

air-activation products since early January 1995, and the location had been roped-off as a Contamination Area. A plastic barrier had been installed to prevent significant air-flow from the beam-line toward experimental areas. Periodic air and daily-contamination surveys had been taken in order to ensure contamination was not spreading. The B5 target was replaced, and the surface areas outside the gate were cleaned-up to the prior low-levels of air-activation products.

A replacement target was installed on March 30. Use of the target was allowed after establishing a lower intensity-limit and installing five-interlocking thermocouples on the platinum target to help ensure the new B5 target would not be damaged.

Since Users' equipment is not normally activated, it was immediately thought on March 27 that the radiation from the equipment was due to contamination from the March 17 incident involving the B5 target. However, the standard, daily beta-emitter surveys taken since March 17 did not show beta contamination on this equipment. Subsequently, a nuclide analysis indicated that the radiation from the equipment was due to the decay of 95-day Os-185 and 53-day Be-7 which do not emit beta radiation. The 20 μR/h from Os-185 and Be-7 is not readily distinguishable from the "sea" of gamma radiation normally measured in the B Test Beam Area. Levels are typically 2000 to 50,000 μR/h during running periods, and 300 to 400 μR/h when all beam lines are off. Thus, contamination of the Users equipment went unnoticed for 10 days, and was found only when the equipment was checked in a low-background area prior to leaving the AGS.

On a basis of a review of inhalation exposures at NRC-licensed and DOE-owned facilities, experience with accidental intakes has been such that workers who are closest to the point of release receive the highest internal radiation exposure.[3, 4, 5, 6, 7]

In accidents involving the release of radioactive materials, experience has been that the magnitude of the maximum inhalation intake is on the order of one-millionth, 10^{-6}, of the amount of unsealed material being processed.[8, 9] This empirically determined number is sometimes called a "magic number" by health physicists. This empirical approach is applicable for processes which confine radioactive material within an enclosure. Examples

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[3] A. Brodsky, J. Schubert, S. Yaniv, K. Lamson, N. Wald, R. Wechsler and R. Caldwell, "Deposition and Retention of ^{192}Ir in the Lung After an Inhalation Incident," Abstracts of the Health Physics Annual Meeting, June 18-22, 1967, Pergamon Press, 1967.

[4] D. A. Cool, W. S. Cool, A. Brodsky, and G. G. Eadie, "Estimation of Long-Term Biological Elimination of Insoluble Iridium-192 from the Human Lung," Health Physics 33, pp.629-632, 1979.

[5] W. D. Norwood, Health Protection of Radiation Workers, Charles C. Thomas, Springfield, IL, 1975.

[6] National Council on Radiation Protection and Measurements, Management of Persons Accidentally Contaminated with Radionuclides, NCRP Report No.65, NCRP Publications, P. O. Box 30175, Washington, DC 20014, 1980.

[5] A. P. Hull, "Preliminary Dose Assessment of the Chernobyl Accident, Parts I-III," The Health Physics Newsletter, Vol. XIV No.12 and Vol. XV No.1 and No.2, Health Physics Society, 1340 Old Chain Bridge Road, Suite 300, McLean, VA 22101, 1986-1987.

[8] A. Brodsky, "Determining Industrial Hygiene Requirements for Installations Using Radioactive Materials," American Industrial Hygiene Association Journal 26, pp.294-310, May-June 1965 and Health Physics 38, pp.1155-1171, June 1980.

[9] A. Brodsky, "Resuspension Factors and Probabilities of Intake of Radioactive Materials in Process (or 'Is 10^{-6} a Magic Number in Health Physics?)", Health Physics 39, pp.992-1000, 1980.

are a glovebox,[10] hood, ion exchange column,[11] or pelletizer within a glovebox.[12] It is noted that in this case, the target is not sealed but is in an enclosure-like area known as a target cave.

We assume for the purpose of this analysis that high temperature is sustainable in the target, for reasons unknown at this time, and that the outermost surfaces or brazed interfaces of the platinum are emanating burned oxides of the various elements produced in the spallation process. It is important to note that the fraction 10^{-6} applies to inhalation intakes only, and that this is the likely mode of intake for trained AGS Users and staff who are trained not to eat or drink in the B Test Beam Area.

Although the target was not visually examined in detail due to the high residual-level of radiation, 50 R/h for the whole target, it did appear that the first two sections of the five-section target broke off from the beryllium base. It was hypothesized at the time that repeated expansion and contraction of the platinum target may have caused it to break as it was hit 1000 times per hour with high-intensity pulses. Subsequently, an additional hypothesis has been put forth in which the platinum target exceeded 1000 °C either during several inadvertent "short" pulses about half the length of a normal SEB pulse, or during a period when melted braze did not allow for sufficient heat transfer. The short pulse phenomenon could occur since the machine has an intrinsic tendency to shorten the spill and operators routinely work to maintain a one second spill. During several short pulses, the braze melted and began to boil. Another hypothesis is a eutectic formed with braze infused with platinum. The eutectic melted at a low temperature and began to boil. Boiling would account for the spotty high contamination and the temperature of 1000 °C would account for creation of and subsequent fuming of the oxide osmium-185.

On the basis of the "magic number" combined with observed body burdens of researchers, and by assuming 40% of the target yielded up some osmium fumes, one can estimate the activity of the source. The estimate of total osmium activity available for dispersion is roughly equivalent, within a factor of 3, to that which would be predicted using the Rudstam formula, the platinum target and the known proton intensity. This is summarized in the following table.

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[10] A. Brodsky, N. Wald, R. E. Lee, J. Horm and R. Caldwell, "Americium Contamination Aspects of a Drybox Incident Involving Hand Amputation" in Health Physics Operational Monitoring, Volume 3, Edited by C. A. Willis and J. S. Handloser, Gorden and Breach, NY, pp.1581-1600, 1972.

[11] R. C. Thompson, Editor, "1976 Hanford Americium Exposure Incident," Special Issue, Health Physics 45, October, 1983.

[12] A. Brodsky, N. Wald, I. S. Horm and B. J. Varzaly, "The Removal of ^{241}Am from Humans by DTPA," Health Physics 17, p.379, 1969.

TABLE 6 - Counting Results Of Personnel Involve In The 3/17/95 AGS B5 Target Incident

Person Exposed	Osmium-185 Body Burden, nCi	Effective Dose Equivalent, mrem	Use of 10^{-6} Magic Number for Estimate of Source, mCi	Osmium -185 in 40% of B5 Target Calculated Using Rudstam Formula, mCi
BNL Technician	25	2	25	560
Student 1	54	4	54	560
Student 2	38	3	38	560
Student 3	7	1	7	560
Student 4	33	2	33	560
Student 5	70	5	70	560
Student 6	60	4	60	560
Project Engineer	10	1	10	560
Researcher 1	181	11	181	560
Researcher 2	150	9	150	560
Researcher 3	15	1	15	560

Researchers 1 and 2 were closest to the B5 target gate which leads to a labyrinth. The target was about 50 feet from the mouth of the labyrinth. Thus, the body burden measurements of Researchers 1 and 2 seem to fall within the rule of thumb of 10^{-6} and seem to indicate the B5 target failure could have been the source of osmium-185.

A review of radionuclides in Table 1 shows three with long half-lives plus other important characteristics. These other characteristics are: 1) they emit at least one distinguishable photon greater than 100 KeV, and 2) the photon yield is greater than 25% per decay. These nuclides are Os-185, Hf-175 and Re-184. Low levels of clearly identifiable Hf-175 have been present in nearly every smear survey performed in the B5 area post B5 target failure. It was measured along with Os-185 in smears. The Handbook of Chemistry and Physics indicates hafnium is pyrophoric; that is, finely divided pieces spontaneously ignite in air, and this may explain its dispersion in the B5 target area.

One may ask why the release of osmium-185 from the B5 target when the platinum target did not look deformed, although the braze material was clearly melted? How could it get to 1000 °C to form a fuming volatile compound like osmium oxide? Other platinum targets in use at AGS look deformed but have not released osmium-185; at least no one has measured osmium-185 in past years.

Several factors may have influenced the creation of a volatile form of osmium. Oxidation or "burning" of some metals occurs at very high temperatures. OsO_4 is dispersible as fumes at low temperatures, 130 °C, but requires higher temperatures to form the oxide. OsO_4 forms at 1000 °C. From recent studies of temperature excursions at C target, a platinum target with a copper base, it appears the target temperature doubled to about 800 °C when the spill length inadvertently decreased from about one second to 0.5 seconds. This phenomenon was observed in March 1996. No damage to C target was initially observed, but the proton intensity was limited to 10 TP indicating 1000 °C could not be achieved even with a short pulse. The temperature was also recorded to be less than 1000

°C. On the basis of the short-pulse phenomenon, however, the B5 target could have risen above 1000 °C at 25 TP, which was the B5 intensity of record on March 17, 1995.

Burning certain metals does not cause them to deform or melt; rather they become powdery and fluffy. Osmium is an example of this. Osmium powder is considered a flammable solid. Many different elements are inside irradiated targets at ppm levels due to spallation, and many different oxides and compounds would form at a temperature of 1000 °C. Some compounds will just stay put, others are very dispersible.

Deformation of metal targets could come from maintaining targets at elevated temperatures, well below melting temperatures, for a long period of time. "Slumping" would be expected to occur if targets are held below the melting point for many months. This may account for the fact that other platinum targets used in the past look deformed but do not release osmium-185. Additionally, a temperature of 1000 °C is needed to create osmium oxide. While C target has been reported to be as high as 30 TP for a few pulses, it would take a combination of purposely sustained high intensity, which was the normal operation at B5, plus a series of short pulses to go above 1000 °C on the C target. In fact, the series of short pulses at C target in March 1996 did not elevate the temperatures above 1000 °C. However, approximately 1 week after the short pulsing event, the C target had to be replaced due to abnormally high temperatures observed during normal running. The C target was damaged in some way and could no longer transfer heat effectively. The damage was not visible to the naked eye when the target was replaced. Interestingly, a smear survey around the area of the damaged C target does not show any osmium-185 which indicates a sustained temperature above 1000 °C may be a necessary requirement for widespread contamination to occur.

Alternatively, the platinum portion of the B5 target appeared normal with no deformations other than two segments falling off. It is possible that the osmium oxide was formed when the platinum target reached high temperatures briefly but the target did not melt. At high temperatures the platinum may have been molten on the inside, but outer portions would retain structure; similar to melting the inside of a jelly bean. Additionally, there would be no discoloration at the surface as evidence of burning since platinum does not tarnish.

Braze between the platinum and beryllium base was seen to be melted on the B5 target. Since the B5 platinum had a brazed surface, it may have been possible to form eutectic thus increasing the possibility of boiling at a much lower temperature than the melting point of any of the individual materials involved. The boiling may have caused spewing of target materials. The melted braze caused a loss of heat transfer which may also cause melting at the platinum-braze interface. Osmium atoms on the surface of the platinum target, or at the site of eutectic, would "burn" in the presence of air or oxygen and become powdery. Inside the target, ppm levels of oxygen are also present due to spallation. Additionally, crystals of spallation products may have been growing inside the target or at the braze interface, while the target looked normal. Unfortunately, the surface of braze

with platinum could not be seen. This interface was covered with globs of braze in the photographs.

Finally, the possibility that the B5 target was not pure platinum was investigated since it may have been a factor influencing the creation of a volatile form of osmium. Osmium is often added to platinum to harden it, as is iridium. A record of the chemical analysis associated with the batch of platinum from which this target was made is shown in Table 7. These levels of contaminants are about 10 times less than the levels of contaminants introduced via activation of the target during irradiation. Activation products are estimated to be at the level of about 1000 ppm for a platinum target after 20 weeks of irradiation.

Table 7 - Analysis of Platinum Melt # PM17044 by Englehard Corporation

Element	Result (ppm)
Pt	999,850 ± 10
Ag	6
Au	16
B	4
Cr	<1
Cu	5
Fe	19
Ir	37
Ni	4
Pd	17
Rh	21
Si	9
Zr	2

Airborne Activity Measurements

The AGS Final Safety Analysis Report (1993) listed a typical target cave volume at $1x10^9$ cm^3 with three air changes per hour due to natural convection. The caves are closed, unventilated spaces, although drafts are observed under doors and near shielding penetrations during operations. The flow rate through a target cave area, which was estimated in 1993, was about $9x10^4$ cm^3/s. This is strikingly similar to the flow rate exhibited by radioactive Cl gas which is predicted to emanate from a platinum target during irradiation at present intensities. Chlorine-39 and Cl-38 have been observed routinely in air outside target-cave gates and measurements are indicated in Table 8. Use of these measurements yields an indirect estimate of the flow rate in the target cave between $8.3x10^4$ and $1.8x10^5$ cm^3/s.

Table 8 - Nuclides Identified on Air Sample Outside C Target Gate in January 1995

Inelastic Cross Section σ, millibarns	Mass of Target Nucleus	Mass of Product Nucleus	Proton Number of Product Nucleus	Nuclide	Half-life, h	Equilibrium Activity (Or Activity at 20 Weeks), mCi	Uniform Activity Release Rate, μCi/s	Measured Activity Concentration Outside C Target Gate on 1/9/95, μCi/cm^3	Estimated Air Flow Rate Through C Target Area, cm^3/s
7.E-04	195.09	39	17	Cl-39	9.00E-01	4.3E-02	7.44E-05	4.20E-10	1.77E+05
4.E-03	195.09	38	17	Cl-38	6.00E-01	2.1E-01	4.96E-05	6.00E-10	8.27E+04

Beryllium

It is important to note the beryllium base in terms of potential hazards should it become dispersed in a cave. This is not likely since the base is maintained well below the temperature of a target; however, the proton beam must be correctly aimed. It is noted that beryllium is a severe poison, a carcinogen, a skin-, lung- and eye-irritant, and an extremely hazardous waste. Thus, target temperature interlocks fortuitously protect the base in the case of the B5 target.

Summary

Platinum targets may be emanating volatile radionuclides routinely. Evidence indicates osmium-185 was released in the correct proportion during an occurrence involving the destruction of the B5 target. Smear samples from C3 and B5 indicate radio-isotopes of Sc, Sb, Eu, V, Mn, Hg, Co, K, Sr, Be, and Na on floor surfaces. Smear surveys from B5 target cave also indicate Hf-175 on many surfaces. Most of these radionuclides are not associated with simple air activation.

Nickel targets will contain and will likely emanate 1000 to 10,000 times more radioactive chlorine atoms than do the current platinum targets. Chlorine is measured in the experimental areas at the levels expected if it is hypothesized to be coming from platinum targets.

Gold targets will contain high inventories of mercury isotopes and may likely emanate radioactive mercury. Gold is reported to fission more readily than was estimated using Rudstam formula and the overall activity estimated here may be an underestimate. Neutron activation of a gold target will add significantly to the residual radiation level. The predicted neutron activation level is well above the radiation level experienced at AGS for the more common platinum target.

The B5 target probably reached a very high temperature just before it broke. This high temperature may have converted many radioactive atoms near the surface of the target into an oxide form. Following this burning event, the target inventory of osmium isotopes may have been released as fuming oxide since OsO_4 is volatile at normal target operating temperatures.

The B5 target was observed to be broken. Within a factor of 3, the "magic number" for body burden was found in researchers close to the B5 target gate. These facts indicate a sudden release of radioactive materials from the B5 target. Additionally, the smear surveys indicate clumps of contamination which could have occurred due to boiling or spewing of small pieces of the B5 target.

Os-185 would be easily measured if it were routinely emanated from platinum targets. Since it is not routinely observed, this may indicate that very high temperatures are needed to make the volatile oxide form. So far, we may have reached these temperatures only at the B5 target.

High intensity protons on targets may be leading to an intolerable combination of high heat and high inventory of radioactivity. The potential for extremely high temperatures over a short period of time exists if cooling fails or if the pulse spill length is shortened. We may be at the point where the combination of high heat and high radioactivity will dictate that all targets be contained on the basis of both routine operations and faults.

Recommendations

It is recommended that AGS either keep oxygen away from targets or use a cold surface near the target to plate out any gases emanating from the target. This cold surface could form a simple containment or enclosure around target. It would be prudent to extend the containment around beryllium bases if they are used with a platinum target.

It is recommended that containment be used around nickel targets for fast extracted beam. This containment will lessen the ambient levels of radio-chlorine gas which would emanate off the target. The radio-chlorines in the V target are expected to be higher by several orders of magnitude than for targets in the slow extracted beam areas. The containment around the V target will also prevent pieces of the target from dispersing throughout the target cave should the rotating nickel plates crack due to high stress events.

Given the potential for a contamination event due to target failure, it is recommended that an elemental analysis of materials used in the fabrication of high-intensity targets be obtained before the materials are exposed to high-intensity beam. It is also recommended that the yield strength of target materials be determined and certified by the AGS Chief Mechanical Engineer prior to exposure to high intensity beam.