ACTIVATION AND SHIELDING

Activation Table of the Elements

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The best way to determine the activation of a sample is to measure it in situ with appropriate instruments. However in planning neutron experiments it may be useful to know whether activation is likely to be significant. Properly estimating activation of a sample by a neutron beam requires knowledge of the neutron spectrum, time of exposure, mass, isotopic composition, etc. The Table below allows you to calculate roughly the activation of a sample after it has been in a neutron beam for one day and the amount of time for it to decay to 74Bq/g (i.e. 2nCi/g) or less, which is a typical limit for shipping a sample as "nonradioactive". It also displays the anticipated exposure you may receive when removing the sample from the instrument. The entries in this table are derived from an approximate calculation (by M. Johnson) for decay times to 10^5 and to 10^4Bq/cm^3 for 5cm^3 pure solid samples of the elements exposed to a neutron beam for 1day at an intensity comparable to that found on HIPD with LANSCE operating at 100μA. These calculations were made for pulsed sources and may somewhat overestimate activation for reactors for some elements (no epithermal neutrons). They are augmented by calculations from NIST of the activation from a 1 day exposure to a 10^7n/s-cm^2 reactor thermal beam (marked †). ***Storage time*** is the time required for a sample of the pure solid element exposed to this "standard" neutron beam to decay to 74Bq/g or less. ***Prompt activation*** gives the anticipated activation for the pure solid elements 2 min after the neutron exposure ceases. ***Contact dose*** is that expected from a 1g sample of the pure element from the prompt activation. Elements with a dash for the entries in all three columns do not show any activation. Those marked with a single asterisk are radioactive before exposure to the neutron beam; apart from Tc and Pm, they are all α-particle emitters. Bismuth is a special case; it is stable before exposure to the

beam, but the activation product is an α-emitter. A typical sample activation calculation may be found in the Web version of the table.

NB: The current Web version of this Table may be found on the ILL Web site: *(http://www.ill.fr/YellowBook/D19/help/act_table.htm).*

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Symbol/Name		Mass	Storage Time	Prompt activation *1 unit=37Bq/g (= 1nCi/g)*	Contact dose at 2.54cm *1 unit=10μGy/hr/g (=1mr/hr/g, at 1 inch)*
Ac	actinium	227	*	*	*
Al	aluminium	26.982	21m	1900	2.0
Am	americium	243	*	*	*
Sb	antimony	121.75	520d	800	0.7
Ar	argon	39.948	19h	3500	3.0
As	arsenic	74.922	18d	8.4×10^4	7.3
At	astatine	210	*	*	*
Ba	barium	137.34	<150h	<80	<0.1
Bk	berkelium	247	*	*	*
Be	beryllium	9.012	-	-	-
Bi	bismuth	208.980	**	**	**
B	boron	10.811	-	-	-
Br	bromine	79.909	18d	1.4×10^4	12†
Cd	cadmium	112.40	190d	370	0.3
Ca	calcium	40.08	-	-	-
Cf	californium	249	*	*	*
C	carbon	12.011	-	-	-
Ce	cerium	140.12	<86h	<40	<0.1
Cs	cesium	132.905	54h	4.6×10^5	400
Cl	chlorine	35.453	<2.8h	<80	<0.1
Cr	chromium	51.996	<61d	<40	<0.1
Co	cobalt	58.933	24y	5.2×10^4	45†
Cu	copper	63.54	7.4d	1.0×10^4	8.5
Cm	curium	247	*	*	*
Dy	dysprosium	162.50	52h	5.0×10^5	430†

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D	deuterium	2.015	-	-	-
Es	einsteinium	254	*	*	*
Er	erbium	167.26	78d	600	0.5
Eu	europium	151.96	50y	2200	1.9†
Fm	fermium	253	*	*	*
F	fluorine	18.998	-	-	-
Fr	francium	223	*	*	*
Gd	gadolinium	157.25	11d	7400	6.4
Ga	gallium	69.72	8d	3.2×10^4	27†
Ge	germanium	72.59	<6d	1100	1.0†
Au	gold	196.967	29d	3000	2.5
Hf	hafnium	178.49	1.6y	620	0.5
He	helium	4.003	-	-	-
Ho	holmium	164.930	20d	2.8×10^4	24†
H	hydrogen	1.008	-	-	-
In	indium	114.82	12d	1.1×10^4	9.5†
I	iodine	126.904	7h	1.2×10^5	100
Ir	iridium	192.2	4.2y	5.0×10^4	43†
Fe	iron	55.847	-	-	-
Kr	krypton	83.80	42h	3200	2.8†
La	lanthanum	138.91	22d	1.9×10^4	16
Pb	lead	207.19	-	-	-
Li	lithium	6.939	-	-	-
Lu	lutetium	174.97	1.8y	1.4×10^4	12†
Mg	magnesium	24.312	-	-	-
Mn	manganese	54.938	38h	1.1×10^5	95
Md	mendelevium	256	*	*	*
Hg	mercury	200.59	24d	700	0.6
Mo	molybdenum	95.94	30d	430	0.4
Nd	neodymium	144.24	15h	1200	1.0
Ne	neon	20.183	-	-	-
Np	neptunium	237	*	*	*
Ni	nickel	58.71	<5.5h	<30	<0.1
Nb	niobium	92.906	80m	2.0×10^4	17
N	nitrogen	14.007	-	-	-

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Os	osmium	190.2	41d	2300	2.0†
O	oxygen	15.999	-	-	-
Pd	palladium	106.4	9d	7.1×10^4	60
P	phosphorus	30.974	-	-	-
Pt	platinum	195.09	20d	230	0.2
Pu	plutonium	242	*	*	*
Po	polonium	210	*	*	*
K	potassium	39.102	<38h	<300	<0.3
Pr	praseodymium	140.907	11d	2.0×10^4	17
Pm	promethium	147	*	*	*
Pa	proctactinium	231	*	*	*
Ra	radium	226	*	*	*
Rn	radon	222	*	*	*
Re	rhenium	186.2	53d	4.9×10^4	42
Rh	rhodium	102.905	2h	2.6×10^4	22†
Rb	rubidium	85.47	56d	1800	1.6
Ru	ruthenium	101.07	106d	230	0.2
Sm	samarium	150.35	35d	6200	5.4
Sc	scandium	44.956	<1.8y	<90	<0.1
Se	selenium	78.96	10h	4900	4.2†
Si	silicon	28.086	-	-	-
Ag	silver	107.870	7.4y	1.6×10^4	14†
Na	sodium	22.991	5.5d	5700	5.0
Sr	strontium	87.62	<25h	<100	<0.1
S	sulphur	32.064	-	-	-
Ta	tantalum	180.948	3y	1600	1.4
Tc	technetium	98	*	*	*
Te	tellurium	127.60	96h	2600	2.2
Tb	terbium	158.924	2.1y	3300	2.8
Tl	thallium	204.37	41m	460	0.4
Th	thorium	232.038	*	*	*
Tm	thulium	168.934	3.7y	7700	6.7†
Sn	tin	118.69	<50d	<40	<0.1
Ti	titanium	47.90	-	-	-

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W	tungsten	183.85	15d	3.7×10^4	32
U	uranium	238.03	*	*	*
V	vanadium	50.942	48m	4.7×10^5	41
Xe	xenon	131.30	7d	3200	2.8
Yb	ytterbium	173.04	275d	780	0.7
Y	yttrium	88.905	24d	1000	0.9
Zn	zinc	65.37	5d	1600	1.4
Zr	zirconium	91.22	79h	<40	<0.1