An updated version of this table is in preparation. Any comments to [Sax Mason]

Activation table of the elements

This table allows you to calculate 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 2nCi/g or less, which is the limit for shipping a sample as "nonradioactive". It also displays the anticipated exposure you may receive when removing the sample from the instrument. A sample calculation is included at the end of the table. *Storage time* is the time required for a sample of the pure condensed-phase element exposed to a "standard" neutron beam to decay to 2nCi/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.

Symbol	**Name**	**Mass**	**Storage time**	**Prompt activation**	**Contact dose**
				(nCi/g)	(mr/hr/g at 1 in)
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	$12^{\dagger}$

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	4.6x10^5	400
Cl	ch1orine	35.453	<2.8h	<80	<0.1
Cr	chromium	5 1.996	<6ld	<40	<0.1
Co	cobalt	58.933	24y	5.2x10^4	45[†]
Cu	copper	63.54	7.4d	1.0x10^4	8.5
Cm	curium	247	*	*	*
Dy	dysprosium	162.50	52h	5.0x10^5	430[†]
D	deuterium	2.015	-	-	-
Es	einsteinium	254	*	*	*
Er	erbium	167.26	78d	600	0.5
Eu	europium	151.96	50y	2200	l.9[†]
Fm	fermium	253	*	*	*
F	fluorine	18.998	-	-	-
Fr	francium	223	*	*	*
Gd	gadolinium	157.25	11d	7400	6.4
Ga	gallium	69.72	8d	3.2x10^4	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	$2.8x10^4$	$24^†$
H	hydrogen	1.008	-	-	-
In	indium	114.82	12d	$1.1x10^4$	$9.5^†$
I	iodine	126.904	7h	$1.2x10^5$	100
Ir	iridium	192.2	4.2y	$5.0x10^4$	$43^†$
Fe	iron	55.847	-	-	-
Kr	krypton	83.80	42h	3200	$2.8^†$
La	lanthanum	138.91	22d	$1.9x10^4$	16
Pb	lead	207.19	-	-	-
Li	lithium	6.939	-	-	-
Lu	lutetium	174.97	1.8y	1.4 $xl0^4$	$12^†$
Mg	magnesium	24.312	-	-	-
Mn	manganese	54.938	38h	$1.lx10^5$	95
Md	mendelevium	256	*	*	*
Hg	mercury	200.59	24d	700	0.6
Mb	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	$2.0x10^4$	17
N	nitrogen	14.007	-	-	-
Os	osmium	190.2	41d	2300	$2.0^†$
O	oxygen	15.999	-	-	-
Pd	palladium	106.4	9d	7. $lx10^4$	60

P	phosphorous	30.974	-	-	-
Pt	platinium	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	$2.0x10^4$	17
Pm	promethium	147	*	*	*
Pa	proctactinium	231	*	*	*
Ra	radium	226	*	*	*
Rn	radon	222	*	*	*
Re	rhenium	186.2	53d	$4.9x10^4$	42
Rh	rhodium	102.905	2h	$2.6x10^4$	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	$l.6x10^4$	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.ly	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	-	-	-
W	tungsten	183.85	15d	$3.7 x 10^4$	32
U	uranium	238.03	*	*	*
V	vanadium	50.942	48m	$4.7 x 10^5$	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

[a]These entries are derived by Mike Johnson of ISIS for decay times to 10^5 and to 10^4Bq/cm^3 for 5-cm^3 pure solid samples of the elements exposed to a neutron beam for 1 day at an intensity comparable to that on HIPD with LANSCE operating at 100μA. 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 †).

Estimating activation

Using the following procedure and example, estimate the anticipated activation of a sample exposed to the neutron beam in a LANSCE instrument from the table. If you cannot estimate the activation, call your LANSCE contact.

Example: For 5g $YBa_2Cu_3O_7$ sample on NPD at 75μA for 24 hours (1 day).

1. Compute the mass fractions for all elements in the sample.

Example: The mass fractions are 0.13 Y, 0.4l Ba, 0.29 Cu, & 0.17 O

2. Obtain the prompt activation from the product of these mass fractions and the corresponding elemental activation values in the table. Multiply the contact dose by the sample mass that is exposed to the beam to obtain the expected contact dose from the entire sample.

Example continued:

prompt activity = 0.13x 1000 + 0.41x80 +0.29x 10000 + 0.17x0.0 = 3060nCi/g

contact dose = 5x(0.13x0.9 + 0.41x0.1 + 0.29x8.5 + 0.17x0.0) = 13.1mR/hr

3. Scale these activation values by the instrumental factor (below) and the beam current as a fraction of l00µA to obtain the estimated values for the sample and actual beam conditions.

Instrumental factors for LANSCE

HIPD 1.00 (reference)
SCD 1.44
FDS 0.50
CQS 1.65
NPD 0.025
PHAROS 0.060
LQD 0.033
SPEAR 0.04 1

Example continued:

prompt activity = 3060x0.025x75/100= 57nCi/g

contact dose = 13.lx0.025x75/100 = 0.25mR/hr

4. To obtain the storage times, t, for each element in the sample, correct the appropriate times given in the table, t_s, by:

$t = t_s(0.693+0.\mathrm{l}x\log_e C)$,

where C is the product of the mass fraction, instrumental factor and beam intensity ratio to l00µ A. This expression assumes that the storage times given in the table are roughly 10 half-lives for the slowest decaying isotope of significant concentration in the activated element The storage time for the sample is then the largest of the resulting times.

Example continued

Y storage time = 24d(0.693+0.lxlog$_e$(0.13x0.025x75/100)) = 2.2d

Ba storage time = 150h(0.693+0.lxlog$_e$(0.41x0.025x75/100)) = 1.3d or less

Cu storage time = 7.4d(0.693+0.lxlog$_e$(0.29x0.025x75/100)) = 1.3d

O storage time = 0 (no activation expected)

Thus the storage time for this sample of $YBa2Cu_3O_7$ is determined by the decay of the Y as 2.2 days. At that time, the sample should show residual activation of less than 2nCi/g.

These estimates are based on a neutron exposure time of 1 day. The actual level of activation can drastically change if the exposure is more or less than 1 day. Determining this change cannot be accomplished using these simplistic calculations. Therefore, we require that all samples (no matter how long the neutron exposure is) be surveyed before they leave the facility.

LANSCE 12 / 1 / 92