

37. Commonly Used Radioactive Sources

Table 37.1. Revised August 2017 by D.E. Groom (LBNL) and R.B. Firestone (LBNL).

Nuclide	Half-life	Type of decay	Particle		Photon	
			Energy (MeV)	Emission prob.	Energy (MeV)	Emission prob.
$^{22}_{11}\text{Na}$	2.603 y	β^+ , EC	0.546	90%	0.511 Annih. 1.275 100%	
$^{51}_{24}\text{Cr}$	27.70 d	EC			0.340 10% V K x rays 100%	
Neutrino calibration source						
$^{54}_{25}\text{Mn}$	0.855 y	EC			0.835 100% Cr K x rays 26%	
$^{55}_{26}\text{Fe}$	2.747 y	EC			Mn K x rays: 0.00590 24.4% 0.00649 2.86%	
$^{57}_{27}\text{Co}$	271.8 d	EC			0.014 9% 0.122 86% 0.136 11% Fe K x rays 58%	
$^{60}_{27}\text{Co}$	5.271 y	β^-	0.317	99.9%	1.173 99.9% 1.333 99.9%	
$^{68}_{32}\text{Ge}$	271.0 d	EC			Ga K x rays 42%	
$\rightarrow ^{68}_{31}\text{Ga}$	67.8 m	β^+ , EC	1.899	90%	0.511 Annih. 1.077 3%	
$^{90}_{38}\text{Sr}$	28.8 y	β^-	0.546	100%		
$\rightarrow ^{90}_{39}\text{Y}$	2.67 d	β^-	2.279	100%		
$^{106}_{44}\text{Ru}$	371.5 d	β^-	0.039	100%		
$\rightarrow ^{106}_{45}\text{Rh}$	30.1 s	β^-	3.546	79%	0.512 21% 0.622 10%	
$^{109}_{48}\text{Cd}$	1.265 y	EC	0.063 e^- 0.084 e^-	42% 44%	0.088 3.7% Ag K x rays 100%	
$^{113}_{50}\text{Sn}$	115.1 d	EC	0.364 e^- 0.388 e^-	28% 6%	0.392 65% In K x rays 97%	
$^{137}_{55}\text{Cs}$	30.0 y	β^-	0.514 1.176	94% 6%	0.662 85%	
$^{133}_{56}\text{Ba}$	10.55 y	EC	0.045 e^- 0.075 e^-	50% 6%	0.081 33% 0.356 62% Cs K x rays 121%	
$^{152}_{63}\text{Eu}$	13.537 y	EC β^-		72.1% 27.9%	Many γ 's 0.1218–1.408 MeV	
$^{207}_{83}\text{Bi}$	32.9 y	EC	0.481 e^- 0.975 e^- 1.047 e^-	2% 7% 2%	0.569 98% 1.063 75% 1.770 7% Pb K x rays 78%	
$^{228}_{90}\text{Th}$	1.912 y	6α : $3\beta^-$:	5.341 to 8.785 0.334 to 2.246		0.239 44% 0.583 31% 2.614 36%	
$(\rightarrow ^{224}_{88}\text{Ra} \rightarrow ^{220}_{86}\text{Rn} \rightarrow ^{216}_{84}\text{Po} \rightarrow ^{212}_{82}\text{Pb} \rightarrow ^{212}_{83}\text{Bi} \rightarrow ^{212}_{84}\text{Po})$ (361 d 55.8 s 0.148 s 10.64 h 60.54 m 300 ns)						
$^{241}_{95}\text{Am}$	432.6 y	α	5.443 5.486	13% 84%	0.060 36% Np L x rays 38%	
$^{241}_{95}\text{Am/Be}$	432.6 y	6×10^{-5} neutrons ($\langle E \rangle = 4$ MeV) and 4×10^{-5} γ 's (4.43 MeV from $^9_4\text{Be}(\alpha, n)$)				
$^{244}_{96}\text{Cm}$	18.11 y	α	5.763 5.805	24% 76%	Pu L x rays \sim 9%	
$^{252}_{98}\text{Cf}$	2.645 y α (97%)		6.076 6.118	15% 82%		
Fission (3.1%): Average 7.8 γ 's/fission; $\langle E_\gamma \rangle = 0.88$ MeV \approx 4 neutrons/fission; $\langle E_n \rangle = 2.14$ MeV						

“Emission probability” is the probability per decay of a given emission; because of cascades these may total more than 100%. Only principal emissions are listed. EC means electron capture, and e^- means monoenergetic internal conversion (Auger) electron. The intensity of 0.511 MeV e^+e^- annihilation photons depends upon the number of stopped positrons. Endpoint β^\pm energies are listed. In some cases when energies are closely spaced, the γ -ray values are approximate weighted averages. Radiation from short-lived daughter isotopes is included where relevant.

Half-lives, energies, and intensities may be found in www-pub.iaea.org/books/IAEABooks/7551/Update-of-X-Ray-and-Gamma-Ray-Decay-Data-Standards-for-Detector-Calibration-and-Other-Applications IAEA (2007) or Nuclear Data Sheets (www.journals.elsevier.com/nuclear-data-sheets) (2007).

Neutron sources: See *e.g.* “Neutron Calibration Sources in the Daya Bay Experiment,” J. Liu *et al.*, Nuclear Instrum. Methods **A797**, 260 (2005) (arXiv:1504.07911).

$^{51}_{24}\text{Cr}$ calibration of neutrino detectors is discussed in *e.g.* Phys. Rev. **B114** (1998). The use of $^{75}_{34}\text{Se}$ and other isotopes has been proposed.