

## 34. COMMONLY USED RADIOACTIVE SOURCES

Table 34.1. Revised November 1993 by E. Browne (LBNL).

Nuclide	Half-life	Type of decay	Particle		Photon	
			Energy (MeV)	Emission prob.	Energy (MeV)	Emission prob.
$^{22}_{11}\text{Na}$	2.603 y	$\beta^+$ , EC	0.545	90%	0.511 Annih. 1.275 100%	
$^{54}_{25}\text{Mn}$	0.855 y	EC			0.835 100% Cr K x rays 26%	
$^{55}_{26}\text{Fe}$	2.73 y	EC			Mn K x rays: 0.00590 24.4% 0.00649 2.86%	
$^{57}_{27}\text{Co}$	0.744 y	EC			0.014 9% 0.122 86% 0.136 11% Fe K x rays 58%	
$^{60}_{27}\text{Co}$	5.271 y	$\beta^-$	0.316	100%	1.173 100% 1.333 100%	
$^{68}_{32}\text{Ge}$	0.742 y	EC			Ga K x rays 44%	
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$\rightarrow ^{68}_{31}\text{Ga}$		$\beta^+$ , EC	1.899	90%	0.511 Annih. 1.077 3%	
$^{90}_{38}\text{Sr}$	28.5 y	$\beta^-$	0.546	100%		
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$\rightarrow ^{90}_{39}\text{Y}$		$\beta^-$	2.283	100%		
$^{106}_{44}\text{Ru}$	1.020 y	$\beta^-$	0.039	100%		
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$\rightarrow ^{106}_{45}\text{Rh}$		$\beta^-$	3.541	79%	0.512 21% 0.622 10%	
$^{109}_{48}\text{Cd}$	1.267 y	EC	0.063 $e^-$ 0.084 $e^-$ 0.087 $e^-$	41% 45% 9%	0.088 3.6% Ag K x rays 100%	
$^{113}_{50}\text{Sn}$	0.315 y	EC	0.364 $e^-$ 0.388 $e^-$	29% 6%	0.392 65% In K x rays 97%	
$^{137}_{55}\text{Cs}$	30.2 y	$\beta^-$	0.514 1.176	94% 6%	0.662 85%	
$^{133}_{56}\text{Ba}$	10.54 y	EC	0.045 $e^-$ 0.075 $e^-$	50% 6%	0.081 34% 0.356 62% Cs K x rays 121%	
$^{207}_{83}\text{Bi}$	31.8 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	$6\alpha$ : $3\beta^-$ :	5.341 to 8.785 0.334 to 2.246		0.239 44% 0.583 31% 2.614 36%	
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$(\rightarrow ^{224}_{88}\text{Ra} \rightarrow ^{220}_{86}\text{Rn} \rightarrow ^{216}_{84}\text{Po} \rightarrow ^{212}_{82}\text{Pb} \rightarrow ^{212}_{83}\text{Bi} \rightarrow ^{212}_{84}\text{Po})$						
$^{241}_{95}\text{Am}$	432.7 y	$\alpha$	5.443 5.486	13% 85%	0.060 36% Np L x rays 38%	
$^{241}\text{Am/Be}$	432.2 y	$6 \times 10^{-5}$ neutrons (4–8 MeV) and $4 \times 10^{-5}\gamma$ 's (4.43 MeV) per Am decay				
$^{244}_{96}\text{Cm}$	18.11 y	$\alpha$	5.763 5.805	24% 76%	Pu L x rays $\sim 9\%$	
$^{252}_{98}\text{Cf}$	2.645 y	$\alpha$ (97%) Fission (3.1%)	6.076 6.118	15% 82%		
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$\approx 20 \gamma$ 's/fission; 80% < 1 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  $\beta^\pm$  energies are listed. In some cases when energies are closely spaced, the  $\gamma$ -ray values are approximate weighted averages. Radiation from short-lived daughter isotopes is included where relevant.

Half-lives, energies, and intensities are from E. Browne and R.B. Firestone, *Table of Radioactive Isotopes* (John Wiley & Sons, New York, 1986), recent *Nuclear Data Sheets*, and *X-ray and Gamma-ray Standards for Detector Calibration*, IAEA-TECDOC-619 (1991).

Neutron data are from *Neutron Sources for Basic Physics and Applications* (Pergamon Press, 1983).