

38. Commonly Used Radioactive Sources

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Table 38.1: Radioactive sources

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			0.320	10%
					V K x rays	
Neutrino calibration source						
$^{54}_{25}\text{Mn}$	0.855 y	EC			0.835	100%
					Cr K x rays	
$^{55}_{26}\text{Fe}$	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	
$^{60}_{27}\text{Co}$	5.271 y	β^-	0.317	99.9%	1.173	99.9%
					1.333	99.9%
$^{68}_{32}\text{Ge}$ \rightarrow $^{68}_{31}\text{Ga}$	271.0 d	EC			Ga K x rays	
					42%	
$^{90}_{38}\text{Sr}$ \rightarrow $^{90}_{39}\text{Y}$	28.8 y	β^-	0.546	100%		
$^{106}_{44}\text{Ru}$ \rightarrow $^{106}_{45}\text{Rh}$	371.5 d	β^-	0.039	100%		
$^{106}_{44}\text{Ru}$ \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^-	42%	0.088	3.7%
			0.084 e^-	44%	Ag K x rays	
$^{113}_{50}\text{Sn}$	115.1 d	EC	0.364 e^-	28%	0.392	65%
			0.388 e^-	6%	In K x rays	
$^{137}_{55}\text{Cs}$	30.0 y	β^-	0.514	94%	0.662	85%
			1.176	6%		

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			Energy (MeV)	Emission prob.	Energy (MeV)	Emission prob.
$^{133}_{56}\text{Ba}$	10.55 y	EC	0.045 e^-	50%	0.081	33%
			0.075 e^-	6%	0.356	62%
					Cs K x rays	121%
$^{152}_{63}\text{Eu}$	13.537 y	EC		72.1%	Many γ 's	
		β^-		27.9%	0.1218–1.408 MeV	
$^{207}_{83}\text{Bi}$	32.9 y	EC	0.481 e^-	2%	0.569	98%
			0.975 e^-	7%	1.063	75%
			1.047 e^-	2%	1.770	7%
					Pb K x rays	78%
$^{228}_{90}\text{Th}$	1.912 y	6α :	5.341 – 8.785		0.239	44%
		$3\beta^-$:	0.334 – 2.246		0.583	31%
					2.614	36%
$\left(\begin{array}{cccccc} \rightarrow & ^{224}_{88}\text{Ra} & \rightarrow & ^{220}_{86}\text{Rn} & \rightarrow & ^{216}_{84}\text{Po} & \rightarrow & ^{212}_{82}\text{Pb} & \rightarrow & ^{212}_{83}\text{Bi} & \rightarrow & ^{212}_{84}\text{Po} \\ & 361 \text{ d} & & 55.8 \text{ s} & & 0.148 \text{ s} & & 10.64 \text{ h} & & 60.54 \text{ m} & & 300 \text{ ns} \end{array} \right)$						
$^{241}_{95}\text{Am}$	432.6 y	α	5.443	13%	0.060	36%
			5.486	84%	Np L x rays	38%
$^{241}_{95}\text{Am}/\text{Be}$	432.6 y	neutrons ($\langle E \rangle = 4 \text{ MeV}$) and γ 's (4.43 MeV from $^9_4\text{Be}(\alpha, n)$)				
$^{244}_{96}\text{Cm}$	18.11 y	α	5.763	24%	Pu L x rays	$\sim 9\%$
			5.805	76%		
$^{252}_{98}\text{Cf}$	2.645 y	α	6.076	15%		
			(97%)	6.118	82%	
Fission (3.1%): Average 7.8 γ 's/fission; $\langle E_\gamma \rangle = 0.88 \text{ MeV}$						
≈ 4 neutrons/fission; $\langle E_n \rangle = 2.14 \text{ MeV}$						

“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.

Isotopic data may be found at https://physics.nist.gov/cgi-bin/Compositions/stand_alone.pl.

Neutron sources: See *e.g.* J. Liu *et al.*, “Neutron Calibration Sources in the Daya Bay Experiment” [1]. $^{51}_{24}\text{Cr}$ calibration of neutrino detectors is discussed in *e.g.* J.N. Abdurashitov *et al.*, “Measurement of the response of a gallium metal solar neutrino experiment to neutrinos from a ^{51}Cr source” [2]. The use of $^{75}_{34}\text{Se}$ and other isotopes has also been proposed.

References

- [1] J. Liu *et al.*, *Nucl. Instrum. Meth. A* **797**, 260 (2015), [arXiv:1504.07911].
 [2] J. N. Abdurashitov *et al.* (SAGE), *Phys. Rev. C* **59**, 2246 (1999), [hep-ph/9803418].