ANNEX 3: TABLE OF PHYSICAL CHARACTERISTICS OF RADIONUCLIDE MENTIONED IN *THE INTERNATIONAL PHARMACOPOEIA*

The values are obtained from the database of the National Nuclear Data Center (NNDC) at Brookhaven National Laboratory, Upton, New York, United States of America, directly accessible via Internet at the address:https://www.nndc.bnl.gov.

More detailed information on physical characteristics including parent half-life, daughter half-life, decay mode, energy, end-point energy intensity, dose and daughter nucleus refer to the IAEA nuclear database (http://www.nndc.bnl.gov/nudat2/ and http://hpschapters.org/northcarolina/nuclide_information_library.php3).

Other data sources:

* DAMRI (Département des Applications et de la Métrologie des Rayonnements Ionisants, CEA Gif-sur-Yvette, France).

** PTB (Physikalisch-Technische Bundesanstalt, Braunschweig, Germany).

*** NPL (National Physical Laboratory, Toddington, Middlesex, United Kingdom of Great Britain and Northern Ireland).

The uncertainty of the half-lives is given in parentheses. In principle, the digits in parentheses are the standard uncertainty of the corresponding last digits of the indicated numerical value (*Guide to the Expression of Uncertainty in Measurement*, International Organization for Standardization (ISO), 1993, ISBN 92-67-10188-9).

The following abbreviations are used:

e_A = Auger electrons

ce = conversion electrons

β^- = electrons

β^+ = positrons

γ = gamma rays

X = X-rays.

Radionuclide	Half-life	Electronic emission			Photon emission		
		Type	[a] Energy (MeV)	[b] Emission probability (per 100 disintegrations)	Type	Energy (MeV)	Emission probability (per 100 disintegrations)
Tritium (^{3}H)	*12.33 (6) years	*β^-	*0.006$^{(I)}$ (max: 0.019)	*100			
Carbon-11 (^{11}C)	20.385 (20) min	β^+	0.386$^{(I)}$ (max: 0.960)	99.8	γ	0.511	199.5$^{(II)}$
Nitrogen-13 (^{13}N)	9.965 (4) min	β^+	0.492$^{(I)}$ (max: 1.198)	99.8	γ	0.511	199.6$^{(II)}$
Oxygen-15 (^{15}O)	122.24 (16) s	β^+	0.735$^{(I)}$ (max: 1.732)	99.9	γ	0.511	199.8$^{(II)}$
Fluorine-18 (^{18}F)	109.77 (5) min	β^+	0.250$^{(I)}$ (max: 0.633)	96.7	γ	0.511	193.5$^{(II)}$
Phosphorus-32 (^{32}P)	14.26 (4) days	β^-	0.695$^{(I)}$	100			

			(max: 1.71)				
Phosphorus-33 (^{33}P)	25.34 (12) days	β^-	0.076[I] (max: 0.249)	100			
Sulphur-35 (^{35}S)	87.51 (12) days	β^-	0.049[I] (max: 0.167)	100			
Chromium-51 (^{51}Cr)	27.7025 (24) days	e_A	0.004	67	X γ	0.005 0.320	22.3 9.9
Cobalt-56 (^{56}Co)	77.27 (3) days	e_A β^+	0.006 0.179[I] 0.631[I]	47 0.9 18.1	X γ	0.006-0.007 0.511 0.847 1.038 1.175 1.238 1.360 1.771 2.015 2.035 2.598 3.202 3.253	25 38.0[II] 100.0 14.1 2.2 66.1 4.3 15.5 3.0 7.8 17.0 3.1 7.6
Cobalt-57 (^{57}Co)	271.79 (9) days	e_A +ce	0.006-0.007 0.014 0.115 0.129	177.4 7.4 1.8 1.3	X γ	0.006-0.007 0.014 0.122 0.136 0.692	57 9.2 85.6 10.7 0.15
Cobalt-58 (^{58}Co)	70.86 (7) days	e_A β^+	0.006 0.201[I]	49.4 14.9	X γ	0.006-0.007 0.511 0.811 0.864 1.675	26.3 29.9[II] 99.4 0.7 0.5
Cobalt-60 (^{60}Co)	5.2714 (5) years	β^-	0.096[I] (max: 0.318)	99.9	γ	1.173 1.333	100.0 100.0
Cobalt-56 (^{56}Co)	77.27 (3) days	e_A β^+	0.006 0.179[I] 0.631[I]	47 0.9 18.1	X γ	0.006-0.007 0.511 0.847 1.038 1.175 1.238 1.360 1.771 2.015 2.035 2.598 3.202 3.253	25 38.0[II] 100.0 14.1 2.2 66.1 4.3 15.5 3.0 7.8 17.0 3.1 7.6
Cobalt-57 (^{57}Co)	271.79 (9) days	e_A +ce	0.006-0.007 0.014 0.115 0.129	177.4 7.4 1.8 1.3	X γ	0.006-0.007 0.014 0.122 0.136 0.692	57 9.2 85.6 10.7 0.15

Cobalt-58 (^{58}Co)	70.86 (7) days	e_A β^+	0.006 0.201[I]	49.4 14.9	X γ	0.006-0.007 0.511 0.811 0.864 1.675	26.3 29.9[II] 99.4 0.7 0.5
Cobalt-60 (^{60}Co)	5.2714 (5) years	β^-	0.096[I] (max: 0.318)	99.9	γ	1.173 1.333	100.0 100.0
Gallium-66 (^{66}Ga)	9.49 (7) hours	e_A β^+	0.008 0.157[I] 0.331[I] 0.397[I] 0.782[I] 1.90[I]	21 1 0.7 3.8 0.3 50	X γ	0.009-0.010 0.511 0.834 1.039 1.333 1.919 2.190 2.423 2.752 3.229 3.381 3.792 4.086 4.295 4.807	19.1 112[II] 5.9 37 1.2 2.1 5.6 1.9 23.4 1.5 1.5 1.1 1.3 4.1 1.8
Gallium-67 (^{67}Ga)	3.2612 (6) days	e_A ce	0.008 0.082-0.084 0.090-0.092 0.175	62 30.4 3.6 0.3	X γ	0.008-0.010 0.091-0.093 0.185 0.209 0.300 0.394 0.888	57 42.4 21.2 2.4 16.8 4.7 0.15
Germanium-68 (^{68}Ga) in equilibrium with Gallium-68 (^{68}Ga)	270.82 (27) days (^{68}Ga: 67.629 (24) min)	e_A β^+	0.008 0.353[I] 0.836[I]	42.4 1.2 88.0	X γ	0.009-0.010 0.511 1.077	44.1 178.3 3.0
Gallium-68 (^{68}Ga)	67.629 (24) min	e_A β^+	0.008 0.353[I] 0.836[I]	5.1 1.2 88.0	X γ	0.009-0.010 0.511 1.077	4.7 178.3 3.0
Krypton-81m (^{81}mKr)	13.10 (3) s	ce	0.176 0.189	26.4 4.6	X γ	0.012-0.014 0.190	17.0 67.6
Rubidium-81 (^{81}Rb) in equilibrium with Krypton-81m (^{81m}Kr)	4.576 (5) hours (^{81m}Kr: 13.10 (3) s)	e_A ce β^+	0.011 0.176 0.188 0.253[I] 0.447[I]	31.3 25.0 4.3 1.8 25.0	X γ	0.013-0.014 0.190 0.446 0.457 0.510 0.511 0.538	57.2 64 23.2 3.0 5.3 54.2 2.2
Strontium-89 (^{89}Sr) in equilibrium with Yttrium-89 (^{89m}Y)	50.53 (7) days (^{89m}Y: 16.06 (4) s)	β^-	0.583[I] (max: 1.492)	99.99	γ	0.909	0.01
Strontium-90 (^{90}Sr)	28.74 (4) days	β^-	0.196[I]	100			

in equilibrium with Yttrium-90 (^{90}Y)	(^{90}Y: 64.10 (8) hours)		(max: 0.546)				
Yttrium-90 (^{90}Y)	64.10 (8) hours	β^-	0.934 (I) (max: 2.280)	100			
Molybdenum-99 (^{99}Mo) in equilibrium with Technetium-99m (^{99m}Tc)	65.94 (1) hours (^{99m}Tc: 6.01 (1) hours)	β^-	0.133(I) 0.290(I) 0.443(I)	16.4 1.1 82.4	X γ	0.018-0.021 0.041 0.141 0.181 0.366 0.740 0.778	3.6 1.1 4.5 6 1.2 12.1 4.3
Technetium-99m (^{99m}Tc)	6.01 (1) hours	ce e_A ce	0.002 0.015 0.120 0.137-0.140	74 2.1 9.4 1.3	X γ	0.018-0.021 0.141	7.3 89.1
Technetium-99 (^{99}Tc)	2.11 x 10^5 years	β^-	0.085(I) (max: 0.294)	100			
Ruthenium-103 (^{103}Ru) in equilibrium with Rhodium-103m (^{103m}Rh)	39.26 (2) days (^{103m}Rh: 56.114 (20) min)	e_A+ ce ce β^-	0.017 0.030-0.039 0.031(I) 0.064(I)	12 88.3 6.6 92.2	X γ	0.020-0.023 0.497 0.610	9.0 91 5.8
Indium-110 (^{110}In)	4.9 (1) hours	e_A	0.019	13.4	X γ	0.023-0.026 0.642 0.658 0.885 0.938 0.997	70.5 25.9 98.3 92.9 68.4 10.5
Indium-110m (^{110m}In)	69.1 (5) min	e_A β^+	0.019 1.015(I)	5.3 61	X γ	0.023-0.026 0.511 0.658 2.129	27.8 123.4(II) 97.8 2.1
Indium-111 (^{111}In)	2.8047 (5) days	e_A ce	0.019 0.145 0.167-0.171 0.219 0.241-0.245	15.6 7.8 1.3 4.9 1.0	X γ	0.003 0.023-0.026 0.171 0.245	6.9 82.3 90.2 94.0
Indium-114m (^{114m}In) in equilibrium with Indium-114 (^{114}In)	49.51 (1) days (^{114}In: 71.9 (1) s)	ce *β^-	0.162 0.186-0.190 0.777(I) (max: 1.985)	40 40 95	X γ	0.023-0.027 0.190 0.558 0.725	36.3 15.6 3.2 3.2
Tellurium-121m (^{121m}Te) in equilibrium with **Tellurium-**121 (^{121}Te)	154.0 (7) days (^{121}Te: 19.16 (5) days)	e_A ce	0.003 0.022-0.023 0.050 0.077 0.180	88.0 7.4 33.2 40.0 6.1	X γ	0.026-0.031 0.212 1.102	50.5 81.4 2.5
Tellurium-121	**19.16	e_A	0.022	11.6	X	0.026-0.030	75.6

(^{121}Te)	(5) days				γ	0.470 0.508 0.573	1.4 17.7 80.3
Iodine-123 (^{123}I)	13.27 (8) hours	e_A ce	0.023 0.127 0.154 0.158	12.3 13.6 1.8 0.4	X γ	0.004 0.027-0.031 0.159 0.346 0.440 0.505 0.529 0.538	9.3 86.6 83.3 0.1 0.4 0.3 1.4 0.4
Iodine-125 (^{125}I)	59.402 (14) days	e_A + ce	0.004 0.023-0.035	80 33	X γ	0.004 0.027 0.031 0.035	15.5 114 26 6.7
Iodine-126 (^{126}I)	13.11 (5) days	e_A ce β^- β^+	0.023 0.354 0.634 0.109(I) 0.290(I) 0.459(I) 0.530(I)	6 0.5 0.1 3.6 32.1 8.0 1	X γ	0.027-0.031 0.388 0.491 0.511 0.666 0.754 0.880 1.420	42.2 34 2.9 2.3(II) 33 4.2 0.8 0.3
Iodine-131 (^{131}I)	8.02070 (11) days	ce β^-	0.46 0.330 0.069(I) 0.097(I) 0.192(I)	3.5 1.6 2.1 7.3 89.9	X γ	0.029-0.030 0.080 0.284 0.365 0.637 0.723	3.9 2.6 6.1 81.7 7.2 1.8
Xenon-131m (^{131m}Xe)	11.84 (7) days	e_A ce	0.025 0.129 0.159 0.163	6.8 61 28.5 8.3	X γ	0.004 0.030 0.034 0.164	8.3 44.0 10.2 2.0
Iodine-133 (^{133}I) (decays to radioactive Xenon-133)	20.8 (1) hours	β^-	0.140(I) 0.162(I) 0.299(I) 0.441(I)	3.8 3.2 4.2 83	γ	0.530 0.875 1.298	87 4.5 2.4
Xenon-133 (^{133}Xe)	5.243 (1) days	e_A ce β^-	0.026 0.045 0.075-0.080 0.101(I)	5.8 55.1 9.9 99.0	X γ	0.004 0.031 0.035 0.080	6.3 40.3 9.4 38.3
Xenon-133m (^{133m}Xe) (decays to radioactive Xenon-133)	2.19 (1) days	e_A ce	0.025 0.199 0.228 0.232	7 64.0 20.7 4.6	X γ	0.004 0.030 0.034 0.233	7.8 45.9 10.6 10.0
Iodine-135 (^{135}I) (decays to radioactive Xenon-135)	6.57 (2) hours	β^-	0.140(I) 0.237 (I) 0.307 (I) 0.352 (I) 0.399 (I) 0.444 (I) 0.529 (I)	7.4 8 8.8 21.9 8 7.5 23.8	γ	*0.527 0.547 0.837 1.039 1.132 1.260 1.458 1.678	13.8 7.2 6.7 8.0 22.7 28.9 8.7 9.6

						1.791	7.8
Xenon-135 (^{135}Xe)	9.14 (2) hours	ce β^-	0.214 0.171 0.308	5.5 3.1 96.0	X γ	0.031-0.035 0.250 0.608	5.0 90.2 2.9
Caesium-137 (^{137}Cs) in equilibrium with Barium-137m (^{137m}Ba)	30.04 (3) years (^{137m}Ba: 2.552 (1) min)	e_A ce β^-	0.026 0.624 0.656 0.174(I) 0.416(I)	0.8 8.0 1.4 94.4 5.6	X γ	0.005 0.032-0.036 0.662	1 7 85.1
Ytterbium-175 (^{175}Yb)	4.185(1) days	e_A ce β^-	0.00602 0.05049 0.1029 0.0190 0.1024 0.1399	6.34 7.42 1.76 20.4 6.7 72.9	X γ	0.0530-0.541 0.1138 0.2825 0.3963	5.90 3.87 6.13 13.2
Lutetium-177m (^{177m}Lu)	160.44(6) days	e_A ce β^-	0.00618 0.04001 0.04760 0.06315 0.08793 0.1017 0.04082(I°)	129.8 33.6 18.2 23.9 16.1 23.9 78.6	X γ	0.0079 0.0546-0.0649 0.2285 0.2818 0.3277 0.3785 0.4137 0.4185	45.6 115.2 37.1 14.2 18.1 29.9 17.5 21.3
Lutetium-177 (^{177}Lu)	6.647(4) days	e_A β^-	4.3-11.2 0.0477 0.1117 0.1494	8.8 11.6 9.1 79.3	X γ	0.007-0.011 0.054-0.056 0.1129 0.2084	3.2 4.4 6.2 10.4
Thallium-200 (^{200}Tl)	26.1 (1) hours	ce β^+	0.285 0.353 0.495(I)	3.4 1.4 0.3	X γ	0.010 0.069-0.071 0.08 0.368 0.579 0.828 1.206 1.226 1.274 1.363 1.515	32.0 63.3 17.5 87.2 13.8 10.8 29.9 3.4 3.3 3.4 4.0
Lead-201 (^{201}Pb) (decays to radioactive Thallium-201)	9.33 (3) hours	e_A ce	0.055 0.246 0.276 0.316	3 8.5 2 2.3	X γ	0.070-0.073 0.083 0.331 0.361 0.406 0.585 0.692 0.767 0.826 0.908 0.946 1.099 1.277	69 19 79 9.9 2.0 3.6 4.3 3.2 2.4 5.7 7.9 1.8 1.6
Thallium-201 (^{201}Tl)	72.912 (17) hours	ce	0.016-0.017 0.027-0.029 0.052 0.084	17.7 4.1 7.2 15.4	X γ	0.010 0.069-0.071 0.080 0.135	46.0 73.7 20.4 2.6

			0.153	2.6		0.167	10.0
Thallium-202 (^{202}Tl)	12.23 (2) days	e_A ce	0.054 0.357	2.8 2.4	X γ	0.010 0.069-0.071 0.080 0.440	31.0 61.6 17.1 91.4
Lead-203 (^{203}Pb)	51.873 (9) hours	e_A ce	0.055 0.194	3.0 13.3	X γ	0.010 0.071-0.073 0.083 0.279 0.401	37.0 69.6 19.4 80.8 3.4
Astatine-211 (^{211}At)	7.214 (7) h	Ec (58.2%) A (42%)					

[a] Mean energy of the β spectrum.

[b] Maximum emission probability corresponding to a total annihilation in the source per 100 disintegrations.