

Parent nuclide	Historic name (short) ^[8]	Historic name (long)	Atomic mass [RS 1]	Decay mode [RS 2]	Branch chance [RS 2]	Half life [RS 2]	Energy released, MeV [RS 2]	Daughter nuclide [RS 2]	Subtotal, MeV
²³⁸ U	U _I	Uranium I	238.051	α	100 %	4.468·10 ⁹ a	4.26975	²³⁴ Th	4.2698
²³⁴ Th	UX ₁	Uranium X ₁	234.044	β^-	100 %	24.10 d	0.273088	^{234m} Pa	4.5428
^{234m} Pa	UX ₂ , Bv	Uranium X ₂ , Brevium	234.043	IT	0.16 %	1.159 min	0.07392	²³⁴ Pa	4.6168
^{234m} Pa	UX ₂ , Bv	Uranium X ₂ , Brevium	234.043	β^-	99.84 %	1.159 min	2.268205	²³⁴ U	6.8110
²³⁴ Pa	UZ	Uranium Z	234.043	β^-	100 %	6.70 h	2.194285	²³⁴ U	6.8110
²³⁴ U	U _{II}	Uranium II	234.041	α	100 %	2.455·10 ⁵ a	4.8598	²³⁰ Th	11.6708
²³⁰ Th	Io	Ionium	230.033	α	100 %	7.54·10 ⁴ a	4.76975	²²⁶ Ra	16.4406
²²⁶ Ra	Ra	Radium	226.025	α	100 %	1600 a	4.87062	²²² Rn	21.3112
²²² Rn	Rn	Radon, Radium Emanation	222.018	α	100 %	3.8235 d	5.59031	²¹⁸ Po	26.9015
²¹⁸ Po	RaA	Radium A	218.009	β^-	0.020 %	3.098 min	0.259913	²¹⁸ At	27.1614
²¹⁸ Po	RaA	Radium A	218.009	α	99.980 %	3.098 min	6.11468	²¹⁴ Pb	33.0162
²¹⁸ At			218.009	β^-	0.1 %	1.5 s	2.881314	²¹⁸ Rn	30.0428
²¹⁸ At			218.009	α	99.9 %	1.5 s	6.874	²¹⁴ Bi	34.0354
²¹⁸ Rn			218.006	α	100 %	35 ms	7.26254	²¹⁴ Po	37.3053
²¹⁴ Pb	RaB	Radium B	214.000	β^-	100 %	26.8 min	1.019237	²¹⁴ Bi	34.0354
²¹⁴ Bi	RaC	Radium C	213.999	β^-	99.979 %	19.9 min	3.269857	²¹⁴ Po	37.3053
²¹⁴ Bi	RaC	Radium C	213.999	α	0.021 %	19.9 min	5.62119	²¹⁰ Tl	39.6566
²¹⁴ Po	RaC ^I	Radium C ^I	213.995	α	100 %	164.3 μ s	7.83346	²¹⁰ Pb	45.1388
²¹⁰ Tl	RaC ^{II}	Radium C ^{II}	209.990	β^-	100 %	1.30 min	5.48213	²¹⁰ Pb	45.1388
²¹⁰ Pb	RaD	Radium D	209.984	β^-	100 %	22.20 a	0.063487	²¹⁰ Bi	45.2022
²¹⁰ Pb	RaD	Radium D	209.984	α	1.9·10 ⁻⁶ %	22.20 a	3.7923	²⁰⁶ Hg	48.9311
²¹⁰ Bi	RaE	Radium E	209.984	β^-	100 %	5.012 d	1.161234	²¹⁰ Po	46.3635
²¹⁰ Bi	RaE	Radium E	209.984	α	13.2·10 ⁻⁵ %	5.012 d	5.03647	²⁰⁶ Tl	50.2387
²¹⁰ Po	RaF	Radium F	209.983	α	100 %	138.376 d	5.40745	²⁰⁶ Pb	51.7709
²⁰⁶ Hg			205.978	β^-	100 %	8.32 min	1.307649	²⁰⁶ Tl	50.2387
²⁰⁶ Tl	RaE ^{II}	Radium E ^{II}	205.976	β^-	100 %	4.202 min	1.532221	²⁰⁶ Pb	51.7709
²⁰⁶ Pb	RaG	Radium G	205.974	stable	–	–	–	–	51.7709

1. "The Risk Assessment Information System: Radionuclide Decay Chain" (<http://rais.ornl.gov/tools/chain.php>). The University of Tennessee.
2. "Evaluated Nuclear Structure Data File" (<https://www-nds.iaea.org/relnsd/NdsEnsd/QueryForm.html>). National Nuclear Data Center.

The mean lifetime of ²³⁸U is 1.41 × 10¹⁷ seconds divided by 0.693 (or multiplied by 1.443), i.e. ca. 2 × 10¹⁷ seconds, so 1 mole of ²³⁸U emits 3 × 10⁶ alpha particles per second, producing the same number of thorium-234 atoms. In a closed system an equilibrium would be reached, with all amounts except for lead-206 and ²³⁸U in fixed ratios, in slowly decreasing amounts. The amount of ²⁰⁶Pb will increase accordingly while that of ²³⁸U decreases; all steps in the decay chain have this same rate of 3 × 10⁶ decayed particles per second per mole ²³⁸U.

Thorium-234 has a mean lifetime of 3 × 10⁶ seconds, so there is equilibrium if one mole of ²³⁸U contains 9 × 10¹² atoms of thorium-234, which is 1.5 × 10⁻¹¹ mole (the ratio of the two half-lives). Similarly, in an equilibrium in a closed system the amount of each decay product, except the end product lead, is proportional to its half-life.

While ²³⁸U is minimally radioactive, its decay products, thorium-234 and protactinium-234, are beta particle emitters with half-lives of about 20 days and one minute respectively. Protactinium-234 decays to uranium-234, which has a half-life of hundreds of millennia, and this isotope does not reach an equilibrium concentration for a very long time. When the two first isotopes in the decay chain reach their relatively small equilibrium concentrations, a sample of initially pure ²³⁸U will emit three times the radiation due to ²³⁸U itself, and most of this radiation is beta particles.

As already touched upon above, when starting with pure ²³⁸U, within a human timescale the equilibrium applies for the first three steps in the decay chain only. Thus, for one mole of ²³⁸U, 3 × 10⁶ times per second one alpha and two beta particles and a gamma ray are produced, together 6.7 MeV, a rate of 3 μW. Extrapolated over 2 × 10¹⁷ seconds this is 600 gigajoules, the total energy released in the first three steps in the decay chain.

Radioactive dating

²³⁸U abundance and its decay to daughter isotopes comprises multiple "uranium dating" techniques and is one of the most common radioactive isotopes used in radiometric dating. The most common dating method is uranium-lead dating, which is used to date rocks older than 1 million years old and has provided ages for the oldest rocks on Earth at 4.4 billion years old.^[9]

The relation between ²³⁸U and ²³⁴U gives an indication of the age of sediments and seawater that are between 100,000 years and 1,200,000 years in age.^[10]

The ²³⁸U daughter product, ²⁰⁶Pb, is an integral part of lead–lead dating, which is most famous for the determination of the age of the Earth.^[11]

The Voyager program spacecraft carry small amounts of initially pure ²³⁸U on the covers of their golden records to facilitate dating in the same manner.^[12]

See also

- Depleted uranium
- Uranium-lead dating

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External links

- NLM Hazardous Substances Databank – Uranium, Radioactive (<http://toxnet.nlm.nih.gov/cgi-bin/sis/search/r?dbs+hsdb:@term+@na+@rel+uranium,+radioactive>)

Lighter: uranium-237	Uranium-238 is an <u>isotope of uranium</u>	Heavier: uranium-239
Decay product of: plutonium-242 (α) protactinium-238 (β-)	Decay chain of uranium-238	Decays to: thorium-234 (α)

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