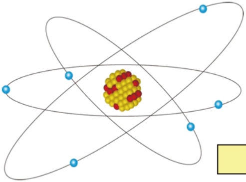
Atomic Structure and Periodic Law



				Charge
Atom	Nucleus	Proton	(red sphere)	+
		Neutron	(yellow sphere)	0
	Electron		(blue sphere)	−

The number of protons (atomic number) determines the chemical properties.

Periodic Table of Elements

Atomic number	Symbol
Atomic weight	

Gas
Liquid
Solid
Form unknown

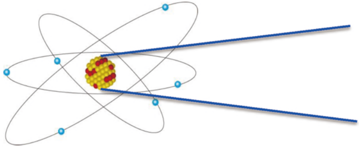
Period \ Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc (99)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	57-71 Lanthanoid	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89-103 Actinoid	104 Rf (267)	105 Db (268)	106 Sg (271)	107 Bh (272)	108 Hs (277)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 Nh (278)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (293)	118 Og (294)

57-71 Lanthanoid	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
89-103 Actinoid	89 Ac (227)	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237)	94 Pu (239)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (252)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

The numbers in parentheses are the nuclear numbers of the typical radioisotopes of the elements (IUPAC).

Prepared based on "One Periodic Table per One Household (11th Edition)": Ministry of Education, Culture, Sports, Science and Technology (MEXT)

Nucleus Stability/Instability



Nucleus

Unstable nuclei exist depending on the balance of numbers between protons and neutrons.
＝Radioactive nuclei

		Carbon-11	Carbon-12	Carbon-13	Carbon-14	Cesium-133	Cesium-134	Cesium-137
Nucleus	Number of protons	6	6	6	6	55	55	55
	Number of neutrons	5	6	7	8	78	79	82
Property		Radioactive	Stable	Stable	Radioactive	Stable	Radioactive	Radioactive
Description method		^{11}C	^{12}C	^{13}C	^{14}C	^{133}Cs	^{134}Cs	^{137}Cs
		$^{11}_{6}C$	$^{12}_{6}C$	$^{13}_{6}C$	$^{14}_{6}C$	$^{133}_{55}Cs$	$^{134}_{55}Cs$	$^{137}_{55}Cs$
		C-11	C-12	C-13	C-14	Cs-133	Cs-134	Cs-137

Radioactive Materials

Various Nuclei

Isotopes: Nuclei having the same number of protons (atom number) but different numbers of neutrons

Element	Symbol	Number of protons	Isotopes	
			Stable	Radioactive
Hydrogen	H	1	H-1, H-2※	H-3※
Carbon	C	6	C-12, C-13	C-11, C-14, ‥
Potassium	K	19	K-39, K-41	K-40, K-42, ‥
Strontium	Sr	38	Sr-84, Sr-86, Sr-87, Sr-88	Sr-89, Sr-90, ‥
Iodine	I	53	I-127	I-125, I-131, ‥
Cesium	Cs	55	Cs-133	Cs-134, Cs-137, ‥
Uranium	U	92	None	U-235, U-238, ‥
Plutonium	Pu	94	None	Pu-238, Pu-239, ‥

*: H-2 is called deuterium and H-3 is called tritium.

". . " means that there are further more radioactive materials. Naturally occurring radioactive materials are shown in blue letters.

Radioactive Materials

Naturally Occurring or Artificial

Radionuclides	Radiation being emitted	Half-life
Thorium-232 (Th-232)	α, γ	14.1 billion years
Uranium-238 (U-238)	α, γ	4.5 billion years
Potassium-40 (K-40)	β, γ	1.3 billion years
Plutonium-239 (Pu-239)	α, γ	24,000 years
Carbon-14 (C-14)	β	5,730 years
Cesium-137 (Cs-137)	β, γ	30 years
Strontium-90 (Sr-90)	β	29 years
Tritium (H-3)	β	12.3 years
Cesium-134 (Cs-134)	β, γ	2.1 years
Iodine-131 (I-131)	β, γ	8 days
Radon-222 (Rn-222)	α, γ	3.8 days

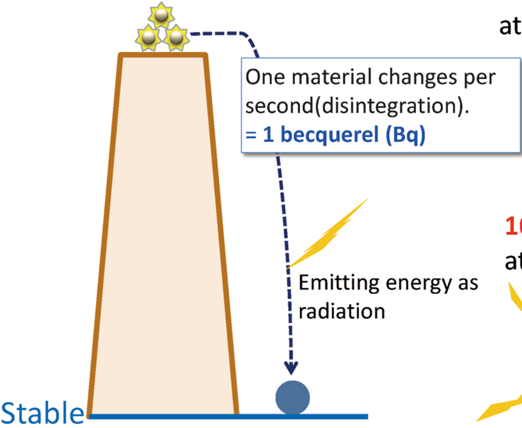
Artificial radionuclides are shown in red letters.

α: α (alpha) particles, β: β (beta) particles, γ: γ (gamma)-rays

Radioactive Materials

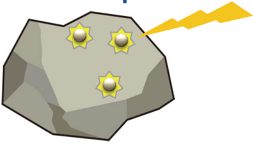
Disintegration and Radiation

Radionuclides are in an unstable condition.

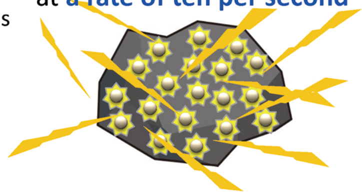


Cease to emit radiation

1 becquerel: Disintegrating at **a rate of one per second**



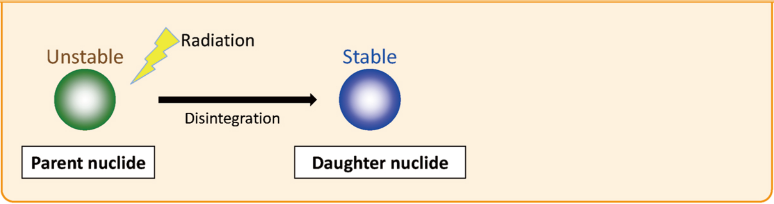
10 becquerel: Disintegrating at **a rate of ten per second**



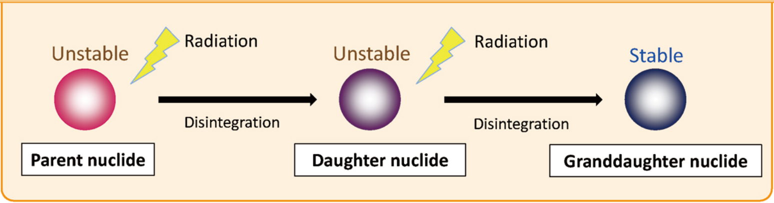
Radioactive Materials

Parent and Daughter Nuclides

Case where a nucleus of a radioactive material becomes energetically stable as a result of a single disintegration

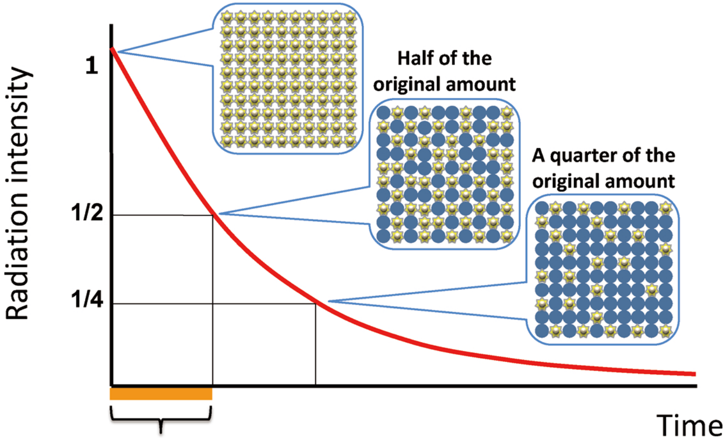


Case where a nucleus of a radioactive material becomes energetically stable as a result of the second disintegration



A nuclide before disintegration is called a parent nuclide and that after disintegration is called a daughter nuclide. A nuclide whose daughter nuclide is energetically unstable repeats disintegration until becoming energetically stable.

Half-lives and Radioactive Decay



Time required for the amount of the radionuclides to reduce to half = (physical) half-life

Nuclei with Long Half-lives

Example Radioactive materials that had existed in the universe since before the birth of the earth and were taken into the earth upon its birth

Series

A radioactive nucleus repeats disintegration until becoming stable, accompanying changes in nuclides each time.

- Uranium-238 (Half-life: 4.5 billion years)
- Thorium-232
- Uranium-235

Non-series

A radioactive nucleus directly disintegrates into a stable nucleus.

- Potassium-40 (Half-life: 1.3 billion years)
- Rubidium-87, etc.