WIKIPEDIA

Isotopes of nickel

Naturally occurring nickel ($_{28}Ni$) is composed of five stable isotopes; ^{58}Ni, ^{60}Ni, ^{61}Ni, ^{62}Ni and ^{64}Ni with ^{58}Ni being the most abundant (68.077% natural abundance).[2] 26 radioisotopes have been characterised with the most stable being ^{59}Ni with a half-life of 76,000 years, ^{63}Ni with a half-life of 100.1 years, and ^{56}Ni with a half-life of 6.077 days. All of the remaining radioactive isotopes have half-lives that are less than 60 hours and the majority of these have half-lives that are less than 30 seconds. This element also has 8 meta states.

Main isotopes of nickel ($_{28}Ni$)

Isotope			Decay	
	abun-dance	half-life ($t_{1/2}$)	mode	pro-duct
^{58}Ni	68.077%	stable		
^{59}Ni	trace	7.6×10^4 y	ε	^{59}Co
^{60}Ni	26.223%	stable		
^{61}Ni	1.140%	stable		
^{62}Ni	3.635%	stable		
^{63}Ni	syn	100 y	β^-	^{63}Cu
^{64}Ni	0.926%	stable		

Standard atomic weight $A_{r,\ standard}(Ni)$ 58.6934(4)[1]

List of isotopes

Nuclide [n 1]	*Z*	*N*	Isotopic mass (u) [n 2][n 3]	Half-life [n 4]	Decay mode [n 5]	Daughter isotope [n 6]	Spin and parity [n 7][n 4]	Natural abundance (mole fraction)	
	Excitation energy							Normal proportion	Range of variation
^{48}Ni	28	20	48.01975(54)#	10# ms [>500 ns]			0+		
^{49}Ni	28	21	49.00966(43)#	13(4) ms [12(+5-3) ms]			7/2−#		
^{50}Ni	28	22	49.99593(28)#	9.1(18) ms	β^+	^{50}Co	0+		
^{51}Ni	28	23	50.98772(28)#	30# ms [>200 ns]	β^+	^{51}Co	7/2−#		
^{52}Ni	28	24	51.97568(9)#	38(5) ms	β^+ (83%)	^{52}Co	0+		
					β^+, p (17%)	^{51}Fe			
^{53}Ni	28	25	52.96847(17)#	45(15) ms	β^+ (55%)	^{53}Co	(7/2−)#		
					β^+, p (45%)	^{52}Fe			
^{54}Ni	28	26	53.95791(5)	104(7) ms	β^+	^{54}Co	0+		
^{55}Ni	28	27	54.951330(12)	204.7(17) ms	β^+	^{55}Co	7/2−		
^{56}Ni	28	28	55.942132(12)	6.075(10) d	β^+	^{56}Co	0+		
^{57}Ni	28	29	56.9397935(19)	35.60(6) h	β^+	^{57}Co	3/2−		
^{58}Ni	28	30	57.9353429(7)	Observationally stable[n 8]			0+	0.680769(89)	
^{59}Ni	28	31	58.9343467(7)	$7.6(5)\times10^4$ y	EC (99%)	**^{59}Co**	3/2−		
					β^+ (1.5×10^{-5}%)[3]				
^{60}Ni	28	32	59.9307864(7)	**Stable**			0+	0.262231(77)	
^{61}Ni	28	33	60.9310560(7)	**Stable**			3/2−	0.011399(6)	
^{62}Ni[n 9]	28	34	61.9283451(6)	**Stable**			0+	0.036345(17)	
^{63}Ni	28	35	62.9296694(6)	100.1(20) y	β^-	**^{63}Cu**	1/2−		
^{63m}Ni	87.15(11) keV			1.67(3) μs			5/2−		
^{64}Ni	28	36	63.9279660(7)	**Stable**			0+	0.009256(9)	
^{65}Ni	28	37	64.9300843(7)	2.5172(3) h	β^-	**^{65}Cu**	5/2−		
^{65m}Ni	63.37(5) keV			69(3) μs			1/2−		
^{66}Ni	28	38	65.9291393(15)	54.6(3) h	β^-	^{66}Cu	0+		
^{67}Ni	28	39	66.931569(3)	21(1) s	β^-	^{67}Cu	1/2−		
^{67m}Ni	1007(3) keV			13.3(2) μs	β^-	^{67}Cu	9/2+		
					IT	^{67}Ni			
^{68}Ni	28	40	67.931869(3)	29(2) s	β^-	^{68}Cu	0+		
^{68m1}Ni	1770.0(10) keV			276(65) ns			0+		
^{68m2}Ni	2849.1(3) keV			860(50) μs			5-		
^{69}Ni	28	41	68.935610(4)	11.5(3) s	β^-	^{69}Cu	9/2+		
^{69m1}Ni	321(2) keV			3.5(4) s	β^-	^{69}Cu	(1/2−)		
					IT	^{69}Ni			
^{69m2}Ni	2701(10) keV			439(3) ns			(17/2−)		
^{70}Ni	28	42	69.93650(37)	6.0(3) s	β^-	^{70}Cu	0+		
^{70m}Ni	2860(2) keV			232(1) ns			8+		
^{71}Ni	28	43	70.94074(40)	2.56(3) s	β^-	^{71}Cu	1/2−#		
^{72}Ni	28	44	71.94209(47)	1.57(5) s	β^- (>99.9%)	^{72}Cu	0+		
					β^-, n (<.1%)	^{71}Cu			

^{73}Ni	28	45	72.94647(32)#	0.84(3) s	β⁻ (>99.9%)	^{73}Cu	(9/2+)		
					β⁻, n (<.1%)	^{72}Cu			
^{74}Ni	28	46	73.94807(43)#	0.68(18) s	β⁻ (>99.9%)	^{74}Cu	0+		
					β⁻, n (<.1%)	^{73}Cu			
^{75}Ni	28	47	74.95287(43)#	0.6(2) s	β⁻ (98.4%)	^{75}Cu	(7/2+)#		
					β⁻, n (1.6%)	^{74}Cu			
^{76}Ni	28	48	75.95533(97)#	470(390) ms [0.24(+55-24) s]	β⁻ (>99.9%)	^{76}Cu	0+		
					β⁻, n (<.1%)	^{75}Cu			
^{77}Ni	28	49	76.96055(54)#	300# ms [>300 ns]	β⁻	^{77}Cu	9/2+#		
^{78}Ni	28	50	77.96318(118)#	120# ms [>300 ns]	β⁻	^{78}Cu	0+		
^{79}Ni	28	51	78.970400(640)#	43.0 ms +86-75	β⁻	^{79}Cu			
^{80}Ni	28	52	78.970400(640)#	24 ms +26-17	β⁻	^{80}Cu			

1. ^{m}Ni – Excited nuclear isomer.
2. ( ) – Uncertainty (1σ) is given in concise form in parentheses after the corresponding last digits.
3. # – Atomic mass marked #: value and uncertainty derived not from purely experimental data, but at least partly from trends from the Mass Surface (TMS).
4. # – Values marked # are not purely derived from experimental data, but at least partly from trends of neighboring nuclides (TNN).
5. Modes of decay:
   EC: Electron capture
   IT: Isomeric transition
   n: Neutron emission
6. **Bold symbol** as daughter – Daughter product is stable.
7. ( ) spin value – Indicates spin with weak assignment arguments.
8. Believed to decay by $\beta^+\beta^+$ to ^{58}**Fe** with a half-life over 7×10^{20} years
9. Highest binding energy per nucleon of all nuclides

Notable isotopes

The 5 stable and 30 unstable isotopes of nickel range in atomic weight from ^{48}Ni to ^{82}Ni, and include:[4]

Nickel-48, discovered in 1999, is the most neutron-poor nickel isotope known. With 28 protons and 20 neutrons ^{48}Ni is "doubly magic" (like ^{208}Pb) and therefore much more stable (with a lower limit of its half-life-time of .5 μs) than would be expected from its position in the chart of nuclides.[5]

Nickel-56 is produced in large quantities in supernovas and the shape of the light curve of these supernovas display characteristic timescales corresponding to the decay of nickel-56 to cobalt-56 and then to iron-56.

Nickel-58 is the most abundant isotope of nickel, making up 68.077% of the natural abundance. Possible sources include electron capture from copper-58 and EC + p from zinc-59.

Nickel-59 is a long-lived cosmogenic radionuclide with a half-life of 76,000 years. ^{59}Ni has found many applications in isotope geology. ^{59}Ni has been used to date the terrestrial age of meteorites and to determine abundances of extraterrestrial dust in ice and sediment.

Nickel-60 is the daughter product of the extinct radionuclide ^{60}Fe (half-life = 2.6 My). Because ^{60}Fe had such a long half-life, its persistence in materials in the solar system at high enough concentrations may have generated observable variations in the isotopic composition of ^{60}Ni. Therefore, the abundance of ^{60}Ni present in extraterrestrial material may provide insight into the origin of the solar system and its early history/very early history. Unfortunately, nickel isotopes appear to have been heterogeneously distributed in the early solar system. Therefore, so far, no actual age information has been attained from ^{60}Ni excesses. ^{60}Ni is also the stable end-product of the decay of ^{60}Zn, the product of the final rung of the alpha ladder. Other sources may also include beta decay from cobalt-60 and electron capture from copper-60.

Nickel-61 is the only stable isotope of nickel with a nuclear spin (I = 3/2), which makes it useful for studies by EPR spectroscopy.[6]

Nickel-62 has the highest binding energy per nucleon of any isotope for any element, when including the electron shell in the calculation. More energy is released forming this isotope than any other, although fusion can form heavier isotopes. For instance, two ^{40}Ca atoms can fuse to form ^{80}Kr plus 4 positrons (plus 4 neutrinos), liberating 77 keV per nucleon, but reactions leading to the iron/nickel region are more probable as they release more energy per baryon.

Nickel-63 has two main uses: Detection of explosives traces, and in certain kinds of electronic devices, such as surge protectors. A surge protector is a device that protects sensitive electronic equipment like computers from sudden changes in the electric current flowing into them. It is also used in Electron capture detector in gas chromatography for the detection mainly of halogens. It is proposed to be used for miniature RTGs for pacemakers.

Nickel-64 is another stable isotope of nickel. Possible sources include beta decay from cobalt-64, and electron capture from copper-64

Nickel-78 is one of the element's heaviest known isotopes. With 28 protons and 50 neutrons, nickel-78 is doubly magic, resulting in much greater nuclear binding energy and stability despite having a lopsided neutron-proton ratio. It has a half-life of 122 ± 5.1 milliseconds.[7] As a consequence of its magic neutron number, nickel-78 is believed to have an important involvement in supernova nucleosynthesis of elements heavier than iron.[8] ^{78}Ni, along with $N = 50$ isotones ^{79}Cu and ^{80}Zn, are thought to constitute a waiting point in the *r*-process, where further neutron capture is delayed by the shell gap and a buildup of isotopes around $A = 80$ results.[9]

References

1. Meija, Juris; et al. (2016). "Atomic weights of the elements 2013 (IUPAC Technical Report)". *Pure and Applied Chemistry*. **88** (3): 265–91. doi:10.1515/pac-2015-0305 (https://doi.org/10.1515%2Fpac-2015-0305).
2. "Isotopes of the Element Nickel" (http://education.jlab.org/itselemental/iso028.html). *Science education*. Jefferson Lab.
3. I. Gresits; S. Tölgyesi (September 2003). "Determination of soft X-ray emitting isotopes in radioactive liquid wastes of nuclear power plants". *Journal of Radioanalytical and Nuclear Chemistry*. **258** (1): 107–112. doi:10.1023/A:1026214310645 (https://doi.org/10.1023%2FA%3A1026214310645).
4. "New nuclides included for the first time in the 2017 evaluation" (https://people.nscl.msu.edu/~thoennes/isotopes-2017/additional-isotopes-2017.pdf) (PDF). Discovery of Nuclides Project. 22 December 2018. Retrieved 22 May 2018.
5. "Discovery of doubly magic nickel" (http://cerncourier.com/cws/article/cern/28206). CERN Courier. 15 March 2000. Retrieved 2 April 2013.
6. Maurice van Gastel; Wolfgang Lubitz (2009). "EPR Investigation of [NiFe] Hydrogenases". In Graeme Hanson; Lawrence Berliner (eds.). *High Resolution EPR: Applications to Metalloenzymes and Metals in Medicine*. Dordrecht: Springer. pp. 441–470. ISBN 9780387848563.
7. Bazin, D. (2017). "Viewpoint: Doubly Magic Nickel" (https://physics.aps.org/articles/v10/121). *Physics*. **10** (121). doi:10.1103/Physics.10.121 (https://doi.org/10.1103%2FPhysics.10.121).
8. Davide Castelvecchi (22 April 2005). "Atom Smashers Shed Light on Supernovae, Big Bang" (http://www.skyandtelescope.com/astronomy-news/atom-smashers-shed-light-on-supernovae-big-bang/). *Sky & Telescope*.
9. Pereira, J.; Aprahamian, A.; Arndt, O.; Becerril, A.; Elliot, T.; Estrade, A.; Galaviz, D.; Hennrich, S.; Hosmer, P.; Kessler, R.; Kratz, K.-L.; Lorusso, G.; Mantica, P.F.; Matos, M.; Montes, F.; Santi, P.; Pfeiffer, B.; Quinn, M.; Schatz, H.; Schertz, F.; Schnorrenberger, L.; Smith, E.; Tomlin, B.E.; Walters, W.; Wöhr, A. (2009). *Beta decay studies of r-process nuclei at the National Superconducting Cyclotron Laboratory*. 10th Symposium on Nuclei in the Cosmos. Mackinac Island. arXiv:0901.1802 (https://arxiv.org/abs/0901.1802).

- Isotope masses from:
  - Audi, Georges; Bersillon, Olivier; Blachot, Jean; Wapstra, Aaldert Hendrik (2003), "The NUBASE evaluation of nuclear and decay properties" (https://hal.archives-ouvertes.fr/in2p3-00020241/document), *Nuclear Physics A*, **729**: 3–128, Bibcode:2003NuPhA.729....3A (https://ui.adsabs.harvard.edu/abs/2003NuPhA.729....3A), doi:10.1016/j.nuclphysa.2003.11.001 (https://doi.org/10.1016%2Fj.nuclphysa.2003.11.001)
- Isotopic compositions and standard atomic masses from:
  - de Laeter, John Robert; Böhlke, John Karl; De Bièvre, Paul; Hidaka, Hiroshi; Peiser, H. Steffen; Rosman, Kevin J. R.; Taylor, Philip D. P. (2003). "Atomic weights of the elements. Review 2000 (IUPAC Technical Report)". *Pure and Applied Chemistry*. **75** (6): 683–800. doi:10.1351/pac200375060683 (https://doi.org/10.1351%2Fpac200375060683).
  - Wieser, Michael E. (2006). "Atomic weights of the elements 2005 (IUPAC Technical Report)". *Pure and Applied Chemistry*. **78** (11): 2051–2066. doi:10.1351/pac200678112051 (https://doi.org/10.1351%2Fpac200678112051). Lay summary (http://old.iupac.org/news/archives/2005/atomic-weights_revised05.html).
- Half-life, spin, and isomer data selected from the following sources.
  - Audi, Georges; Bersillon, Olivier; Blachot, Jean; Wapstra, Aaldert Hendrik (2003), "The NUBASE evaluation of nuclear and decay properties" (https://hal.archives-ouvertes.fr/in2p3-00020241/document), *Nuclear Physics A*, **729**: 3–128, Bibcode:2003NuPhA.729....3A (https://ui.adsabs.harvard.edu/abs/2003NuPhA.729....3A), doi:10.1016/j.nuclphysa.2003.11.001 (https://doi.org/10.1016%2Fj.nuclphysa.2003.11.001)
  - National Nuclear Data Center. "NuDat 2.x database" (http://www.nndc.bnl.gov/nudat2/). Brookhaven National Laboratory.
  - Holden, Norman E. (2004). "11. Table of the Isotopes". In Lide, David R. (ed.). *CRC Handbook of Chemistry and Physics* (85th ed.). Boca Raton, Florida: CRC Press. ISBN 978-0-8493-0485-9.
  - IAEA - Nuclear Data Section. "Livechart - Table of Nuclides" (https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html). IAEA - Nuclear Data Section. Retrieved 23 May 2018.