Nickel

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Nickel is a chemical element with symbol **Ni** and atomic number 28. It is a silvery-white lustrous metal with a slight golden tinge. Nickel belongs to the transition metals and is hard and ductile. Pure nickel, powdered to maximize the reactive surface area, shows a significant chemical activity, but larger pieces are slow to react with air under standard conditions because an oxide layer forms on the surface and prevents further corrosion (passivation). Even so, pure native nickel is found in Earth's crust only in tiny amounts, usually in ultramafic rocks,[4][5] and in the interiors of larger nickel–iron meteorites that were not exposed to oxygen when outside Earth's atmosphere.

Meteoric nickel is found in combination with iron, a reflection of the origin of those elements as major end products of supernova nucleosynthesis. An iron–nickel mixture is thought to compose Earth's inner core.[6]

Use of nickel (as a natural meteoric nickel–iron alloy) has been traced as far back as 3500 BCE. Nickel was first isolated and classified as a chemical element in 1751 by Axel Fredrik Cronstedt, who initially mistook the ore for a copper mineral. The element's name comes from a mischievous sprite of German miner mythology, Nickel (similar to Old Nick), that personified the fact that copper-nickel ores resisted refinement into copper. An economically important source of nickel is the iron ore limonite, which often contains 1–2% nickel. Nickel's other important ore minerals include garnierite, and pentlandite. Major production sites include the Sudbury region in Canada (which is thought to be of meteoric origin), New Caledonia in the Pacific, and Norilsk in Russia.

Nickel oxidizes slowly at room temperature and is considered corrosion-resistant. Historically, it has been used for plating iron and brass, coating chemistry equipment, and manufacturing certain alloys that retain a high silvery polish, such as German silver. About 6% of world nickel production is still used for corrosion-resistant pure-nickel plating. Nickel-plated objects sometimes provoke nickel allergy. Nickel has been widely used in coins, though its rising price has led to some replacement with cheaper metals in recent years.

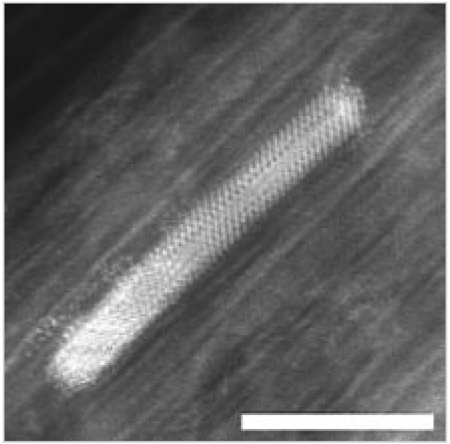
Nickel, $_{28}$Ni

General properties	
Name, symbol	nickel, Ni
Appearance	lustrous, metallic, and silver with a gold tinge
Nickel in the periodic table	
Atomic number (*Z*)	28
Group, block	group 10, d-block
Period	period 4
Element category	□ transition metal
Standard atomic weight (±) (A_r)	58.6934(4)[1]
Electron configuration	[Ar] $3d^8$ $4s^2$ *or* [Ar] $3d^9$ $4s^1$
per shell	2, 8, 16, 2 *or* 2, 8, 17, 1

Nickel is one of four elements (iron, cobalt, nickel, and gadolinium)[7] that are ferromagnetic around room temperature. Alnico permanent magnets based partly on nickel are of intermediate strength between iron-based permanent magnets and rare-earth magnets. The metal is valuable in modern times chiefly in alloys; about 60% of world production is used in nickel-steels (particularly stainless steel). Other common alloys and some new superalloys comprise most of the remainder of world nickel use, with chemical uses for nickel compounds consuming less than 3% of production.[8] As a compound, nickel has a number of niche chemical manufacturing uses, such as a catalyst for hydrogenation. Nickel is an essential nutrient for some microorganisms and plants that have enzymes with nickel as an active site.

Properties

Atomic and physical properties



TEM image of a Ni nanocrystal inside a single wall carbon nanotube segment; scale bar 5 nm.[9]

Nickel is a silvery-white metal with a slight golden tinge that takes a high polish. It is one of only four elements that are magnetic at or near room temperature, the others being iron, cobalt and gadolinium. Its Curie temperature is 355 °C (671 °F), meaning that bulk nickel is non-magnetic above this temperature.[10] The unit cell of nickel is a face-centered cube with the lattice parameter of 0.352 nm, giving an atomic radius of 0.124 nm. This crystal structure is stable to pressures of at least 70 GPa. Nickel belongs to the transition metals and is hard and ductile.

Electron configuration dispute

The nickel atom has two electron configurations, [Ar] $3d^8$ $4s^2$ and [Ar] $3d^9$ $4s^1$, which are very close in energy – the symbol [Ar] refers to the argon-like core structure. There is some disagreement on which configuration has the lowest energy.[11] Chemistry textbooks quote the electron configuration of nickel as [Ar] $4s^2$ $3d^8$,[12] which can also be

Physical properties

Phase	solid
Melting point	1728 K (1455 °C, 2651 °F)
Boiling point	3003 K (2730 °C, 4946 °F)
Density near r.t.	8.908 g/cm^3
when liquid, at m.p.	7.81 g/cm^3
Heat of fusion	17.48 kJ/mol
Heat of vaporization	379 kJ/mol
Molar heat capacity	26.07 J/(mol·K)

Vapor pressure

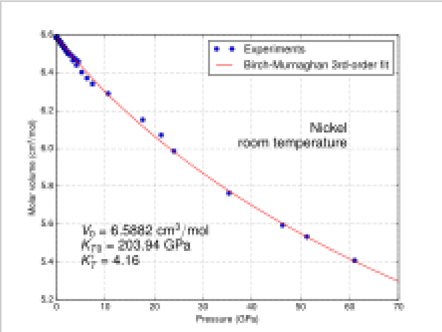
P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	1783	1950	2154	2410	2741	3184

Atomic properties

Oxidation states	4,[2] 3, **2**, 1,[3] −1, −2 (a mildly basic oxide)
Electronegativity	Pauling scale: 1.91
Ionization energies	1st: 737.1 kJ/mol 2nd: 1753.0 kJ/mol 3rd: 3395 kJ/mol (more)
Atomic radius	empirical: 124 pm
Covalent radius	124±4 pm
Van der Waals radius	163 pm

Miscellanea

Crystal structure	face-centered cubic (fcc)



Molar volume vs. pressure at room temperature

written [Ar] 3d^8 4s^2.[13] This configuration agrees with the Madelung energy ordering rule, which predicts that 4s is filled before 3d. It is supported by the experimental fact that the lowest energy state of the nickel atom is a 3d^8 4s^2 energy level, specifically the 3d^8(^{3}F) 4s^2 ^{3}F, J = 4 level.[14]

However, each of these two configurations gives rise to several energy levels,[14] and the two sets of energy levels overlap. The average energy of states with configuration [Ar] 3d^9 4s^1 is actually lower than the average energy of states with configuration [Ar] 3d^8 4s^2. For this reason, the research literature on atomic calculations quotes the ground state configuration of nickel as [Ar] 3d^9 4s^1.[11]

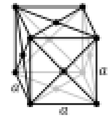
Isotopes

The isotopes of nickel range in atomic weight from 48 u (^{48}Ni) to 78 u (^{78}Ni).

Naturally occurring nickel 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). Isotopes heavier than ^{62}Ni cannot be formed by nuclear fusion without losing energy.

Nickel-62 has the highest nuclear binding energy of any nuclide, at 8.7946 MeV/nucleon.[15] Its binding energy is greater than both ^{56}Fe, often incorrectly cited as the most tightly-bound nuclide, and it is also more tightly bound than ^{58}Fe.[16]

Stable isotope nickel-60 is the daughter product of the extinct radionuclide ^{60}Fe, which decays with a half-life of 2.6 million years. Because ^{60}Fe has such a long half-life, its persistence in materials in the solar system may generate 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.



Speed of sound thin rod	4900 m/s (at r.t.)
Thermal expansion	13.4 µm/(m·K) (at 25 °C)
Thermal conductivity	90.9 W/(m·K)
Electrical resistivity	69.3 nΩ·m (at 20 °C)
Magnetic ordering	ferromagnetic
Young's modulus	200 GPa
Shear modulus	76 GPa
Bulk modulus	180 GPa
Poisson ratio	0.31
Mohs hardness	4.0
Vickers hardness	638 MPa
Brinell hardness	667–1600 MPa
CAS Number	7440-02-0
History	
Discovery and first isolation	Axel Fredrik Cronstedt (1751)
Most stable isotopes of nickel	

Some 18 nickel radioisotopes have been characterised, the most stable being ^{59}Ni with a half-life of 76,000 years, ^{63}Ni with 100.1 years, and ^{56}Ni with 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 one meta state.[17]

iso	NA	half-life	DM	DE (MeV)	DP
^{58}Ni	68.077%	is stable with 30 neutrons			
^{59}Ni	trace	7.6×10^{4} y	ε	0.0506	^{59}Co
^{60}Ni	26.223%	is stable with 32 neutrons			
^{61}Ni	1.140%	is stable with 33 neutrons			
^{62}Ni	3.635%	is stable with 34 neutrons			
^{63}Ni	syn	100.1 y	β^-	0.0669	^{63}Cu
^{64}Ni	0.926%	is stable with 36 neutrons			

Radioactive nickel-56 is produced by the silicon burning process and later set free in large quantities during type Ia supernovae. The shape of the light curve of these supernovae at intermediate to late-times corresponds to the decay via electron capture of nickel-56 to cobalt-56 and ultimately to iron-56.[18] 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-78's half-life was recently measured at 110 milliseconds, and is believed an important isotope in supernova nucleosynthesis of elements heavier than iron.[19] The nuclide ^{48}Ni, discovered in 1999, is the most proton-rich heavy element isotope known. With 28 protons and 20 neutrons ^{48}Ni is "double magic" (like ^{208}Pb) and therefore unusually stable.[17][20]

External links

- Wikipedia: Nickel (https://en.wikipedia.org/wiki/Nickel)