

## 4. CHEMICAL AND PHYSICAL INFORMATION

### 4.1 CHEMICAL IDENTITY

Nickel is a transition metal in group VIII of the periodic table following iron and cobalt (Cotton and Wilkinson 1980). Its outer shell of electrons has a  $4s^23d^8$  configuration. While nickel can exist in oxidation states -1, 0, +2, +3, and +4, its only important oxidation state is nickel(+2) under normal environmental conditions.

Nickel forms useful alloys with many metals. It is added to metals to increase their hardness, strength, and corrosion resistance. The most familiar are nickeliferous alloys used in stainless steel and copper-nickel alloys used in coinage metal.

Nickel oxide also comes in a black crystalline form that has a slightly higher oxygen content than its formula, NiO (Antonsen 1981). The nickel content of black nickel oxide is 76–77% compared with 78.5% for the more stable green nickel oxide. Nickel ammonium sulfate, nickel sulfate, nickel chloride, and nickel nitrate usually exist as hexahydrates, while nickel acetate, nickel cyanide, and nickel sulfamate are in the form of a tetrahydrate.

Information regarding the chemical identity of nickel is located in Table 4-1.

### 4.2 PHYSICAL AND CHEMICAL PROPERTIES

Metallic nickel is a hard, lustrous, silvery white metal, which, in its bulk form, is resistant to attack by air and water at ordinary temperatures. However, powdered nickel is reactive in air and may spontaneously ignite.

Nickel has typical metallic properties; it can be readily rolled, drawn into wire, forged, and polished. It is also ferromagnetic and a good conductor of both heat and electricity. Nickel is positioned after hydrogen in the electrochemical series and slowly displaces hydrogen ions from dilute hydrochloric and sulfuric acids. It reacts more rapidly with nitric acid. Nickel is highly resistant to attack by strong alkalis (Hawley 1981). Black nickel oxide readily yields nickel salts in the presence of acids (WHO 1991).

## 4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-1. Chemical Identity of Nickel and Compounds<sup>a</sup>**

Characteristic	Nickel	Nickel acetate	Nickel ammonium sulfate
Synonyms	CI 77775; Nickel 200; Nickel 201; Nickel 205; Nickel 270; Alnico <sup>b</sup> ; NP 2 <sup>b</sup>	Acetic acid, nickel(2+) salt; nickel diacetate; nickelous acetate; nickel(II) acetate	Ammonium nickel sulfate; sulfuric acid, ammonium nickel(2+) salt; ammonium disulfatonickelate(II)
Registered trade name(s)	Monel <sup>b</sup> ; Inconel <sup>b</sup> ; Icoloy <sup>b</sup> ; Raney nickel <sup>c</sup> ; Nimonic <sup>d</sup> ; Hastelloy <sup>d</sup> ; Udimet <sup>d</sup> ; Mar M <sup>d</sup> ; René 41 <sup>d</sup> ; Waspaloy <sup>d</sup>	No data	No data
Chemical formula	Ni	Ni(CH <sub>3</sub> CO <sub>2</sub> ) <sub>2</sub>	Ni(NH <sub>4</sub> ) <sub>2</sub> (SO <sub>4</sub> ) <sub>2</sub>
Chemical structure	Ni	$\left[ \text{Ni}^{2+} \right] \left[ \text{H}_3\text{C}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}^- \right]_2$	$\left[ \text{Ni}^{2+} \right] \left[ \text{NH}_4^+ \right] \left[ \text{O}-\overset{\text{O}}{\parallel}{\text{S}}-\text{O}^{2-} \right]_2$
Identification numbers:			
CAS registry	7440-02-0	373-02-4	15699-18-0
NIOSH RTECS	QR5950000 <sup>d</sup>	QR6125000	WS6050000 <sup>d</sup>
EPA hazardous waste	No data	No data	No data
OHM/TADS	No data	No data	No data
DOT/UN/NA/IMCO shipping	No data	No data	No data
HSDB	1096	1029	1241
NCI	No data	No data	No data

## 4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-1. Chemical Identity of Nickel and Compounds<sup>a</sup>**

Characteristic	Nickel carbonate	Nickel chloride	Nickel cyanide
Synonyms	CI 77779; Carbonic acid, nickel(2+) salt; nickel (II) carbonate; nickelous carbonate; nickel monocarbonate	Nickel(II) chloride; nickel dichloride; nickelous chloride	Nickel(II) cyanide; nickel dicyanide; dicyanonickel
Registered trade name(s)	No data	No data	No data
Chemical formula	NiCO <sub>3</sub>	NiCl <sub>2</sub>	Ni(CN) <sub>2</sub>
Chemical structure	$\left[ \text{Ni}^{2+} \right] \left[ \begin{array}{c} \text{O} \\ \parallel \\ \text{O}-\text{C}-\text{O} \\   \\ \text{O} \end{array} \right]^{2-}$	Cl – Ni – Cl	NC – Ni – CN
Identification numbers:			
CAS registry	3333-67-3	7718-54-9	557-19-7
NIOSH RTECS	QR6200000 <sup>d</sup>	QR6475000 <sup>d</sup>	QR6495000 <sup>d</sup>
EPA hazardous waste	No data	No data	No data
OHM/TADS	No data	No data	No data
DOT/UN/NA/IMCO shipping	No data	No data	UN1653
HSDB	1662	860	1185
NCI	No data	No data	No data

## 4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-1. Chemical Identity of Nickel and Compounds<sup>a</sup>**

Characteristic	Nickel oxide	Nickel nitrate	Nickel subsulfide
Synonyms	Bunsenite; CI 77777; green nickel oxide; mononickel oxide; nickel(II) oxide; nickelous oxide; nickel monoxide <sup>b</sup> ; nickel oxide sinter 75 <sup>b</sup> ; nickel protoxide; mononickel	Nitric acid, nickel(2+) salt, nickelous nitrate; nickel dinitrate; nickel(II) nitrate	Trinickel disulfide <sup>b</sup> ; nickel sulfide; Heazlewoodite; nickel sesquisulfide <sup>b</sup> ; khislevudite <sup>b</sup> ; nickel tritadisulfide
Registered trade name(s)	Nickel oxide	No data	No data
Chemical formula	NO	Ni(NO <sub>3</sub> ) <sub>2</sub>	Ni <sub>3</sub> S <sub>2</sub>
Chemical structure	Ni – O	$\left[ \text{Ni}^{2+} \right] \left[ \begin{array}{c} \text{O} \\ \parallel \\ \text{O}-\text{N}-\text{O} \\   \\ \text{O} \end{array} \right]_2$	No data
Identification numbers:			
CAS registry	1313-99-1	13138-45-9	12035-72-2
NIOSH RTECS	QR8400000 <sup>d</sup>	QR7200000 <sup>d</sup>	QR9800000 <sup>d</sup>
EPA hazardous waste	No data	No data	No data
OHM/TADS	No data	No data	No data
DOT/UN/NA/IMCO shipping	No data	UN 27525; IMO 5.1	No data
HSDB	1664	1829	2965
NCI	No data	No data	No data

## 4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-1. Chemical Identity of Nickel and Compounds<sup>a</sup>**

Characteristic	Nickel sulfamate	Nickel sulfate
Synonyms	Sulfamic acid, nickel(2+) salt <sup>d</sup> ; Nickel amidosulfate <sup>e</sup> ; Nickel (II) sulfamate <sup>e</sup> ; Aeronikl 250 <sup>d</sup> ; Aeronikl 400 <sup>d</sup> ; Aeronikl 575 <sup>d</sup>	Nickel monosulfate; nickelous sulfate; nickel(II) sulfate; sulfuric acid nickel salt <sup>b</sup>
Registered trade name(s)	No data	No data
Chemical formula	Ni(NH <sub>2</sub> SO <sub>3</sub> ) <sub>2</sub>	NiSO <sub>4</sub>
Chemical structure	$\left[ \text{Ni}^{2+} \right] \left[ \text{H}_2\text{N}-\overset{\text{O}}{\parallel}{\text{S}}-\overset{-}{\text{O}} \right]_2$	$\left[ \text{Ni}^{2+} \right] \left[ \overset{\text{O}}{\parallel}{\text{O}}-\overset{2-}{\text{S}}-\overset{\text{O}}{\parallel}{\text{O}} \right]$
Identification numbers:		
CAS registry	13770-89-3 <sup>d</sup>	7786-81-4
NIOSH RTECS	QR9275000 <sup>d</sup>	QR9350000 <sup>d</sup>
EPA hazardous waste	No data	No data
OHM/TADS	No data	No data
DOT/UN/NA/IMCO shipping	No data	ID8027
HSDB	No data	1114
NCI	No data	NCI-C60344 <sup>d</sup>

<sup>a</sup>All information obtained from HSDB 2004 except where noted.

<sup>b</sup>Czerczak and Gromiec 2001

<sup>c</sup>Tien and Howson 1981; Windholz 1983. Names refer to alloys of nickel. Generally, there is a series of alloys with the same trade name (e.g., Monel alloy K-400, Monel alloy K-500).

<sup>d</sup>RTECS 2004

<sup>e</sup>Laschelles and Nicholls 1991

CAS = Chemical Abstracts Service; DOT/UN/NA/IMCO = Department of Transportation/United Nations/North America/International Maritime Dangerous Goods Code; EPA = Environmental Protection Agency; HSDB = Hazardous Substances Data Bank; NCI = National Cancer Institute; Ni = nickel; NIOSH = National Institute for Occupational Safety and Health; OHM/TADS = Oil and Hazardous Materials/Technical Assistance Data System; RTECS = Registry of Toxic Effects of Chemical Substances

## 4. CHEMICAL AND PHYSICAL INFORMATION

Information regarding the physical and chemical properties of nickel and compounds is located in Table 4-2.

## 4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-2. Physical and Chemical Properties of Nickel and Compounds<sup>a</sup>**

Property	Nickel	Nickel acetate	Nickel ammonium sulfate	Nickel carbonate
Molecular weight	58.69	176.80	286.90	118.70
Color	Silvery	Green	Blue-green	Green
Physical state	Solid	Solid	Solid	Solid
Melting point	1,455 °C	Decomposes	No data	Decomposes
Boiling point	2,730 °C	16.6 °C; decomposes <sup>b</sup>	No data	No data
Density	8.91 g/cm <sup>3</sup>	1.798 g/cm <sup>3</sup>	1.923 g/cm <sup>3</sup>	4.39 g/cm <sup>3</sup>
Odor	Odorless	Acetic odor	Odorless	No data
Odor threshold:				
Water	No data	No data	No data	No data
Air	No data	No data	No data	No data
Solubility:				
Water	1.13 mg/L at 37 °C <sup>c</sup>	17 weight% at 68 °C	104 g/L at 20 °C	93 mg/L at 25 °C
Organic solvents	No data	Insoluble in alcohol	Insoluble in alcohol	No data
Partition coefficients:				
K <sub>ow</sub>	No data	No data	No data	No data
K <sub>oc</sub>	No data	No data	No data	No data
Vapor pressure	1 mmHg at 1,810 °C	No data	No data	No data
Henry's law constant	No data	No data	No data	No data
Autoignition temperature	No data	No data	Nonflammable	Nonflammable
Flashpoint	No data	No data	Nonflammable	Nonflammable
Flammability limits	No data	No data	Nonflammable	Nonflammable
Conversion factor	No data	No data	No data	No data
Explosive limits	No data	No data	No data	No data

## 4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-2. Physical and Chemical Properties of Nickel and Compounds<sup>a</sup>**

Property	Nickel chloride	Nickel cyanide	Nickel oxide	Nickel nitrate
Molecular weight	129.60	110.73	74.69	182.72
Color	Golden yellow	Yellow brown	Green or black	Green
Physical state	Solid	Solid	Solid	Solid
Melting point	1,001 °C	>200 °C	1,955 °C	56.7 °C <sup>c</sup>
Boiling point	Sublimes at 973 °C	Decomposes	No data	136.7 °C <sup>c</sup>
Density	3.55 g/cm <sup>3</sup>	2.393 g/cm <sup>3</sup>	6.72 g/cm <sup>3</sup>	2.05 g/cm <sup>3d</sup>
Odor	None	Weak almond odor	No data	No data
Odor threshold:				
Water	No data	No data	No data	No data
Air	No data	No data	No data	No data
Solubility:				
Water	642 g/L at 20 °C	Insoluble	1.1 mg/L at 20 °C	2,385 g/L at 0 °C <sup>d</sup> ; 48.5 weight% at 20 °C <sup>d</sup>
Organic solvents	Soluble in ethanol; 180 g/L at 20 °C in ethylene glycol	No data	No data	Insoluble in alcohol <sup>c</sup> ; soluble in alcohol <sup>d</sup>
Partition coefficients:				
K <sub>ow</sub>	No data	No data	No data	No data
K <sub>oc</sub>	No data	No data	No data	No data
Vapor pressure	1 mmHg at 671 °C	No data	No data	No data
Henry's law constant	No data	No data	No data	No data
Autoignition temperature	Nonflammable	Nonflammable	No data	No data
Flashpoint	Nonflammable	Nonflammable	No data	No data
Flammability limits	Nonflammable	Nonflammable	No data	No data
Conversion factor	No data	No data	No data	No data
Explosive limits	No data	No data	No data	No data



## 4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-2. Physical and Chemical Properties of Nickel and Compounds<sup>a</sup>**

Property	Nickel subsulfide	Nickel sulfamate	Nickel sulfate
Molecular weight	240.212	322.94 <sup>f,g</sup>	154.75
Color	Pale yellowish <sup>e</sup>	No data	Greenish-yellow
Physical state	Solid	Solid	Solid
Melting point	787 °C	No data	840 °C
Boiling point	No data	No data	Decomposes at 840 °C
Density	5.87 g/cm <sup>3</sup>	No data	4.01 g/cm <sup>3</sup>
Odor	No data	No data	Odorless
Odor threshold:			
Water	No data	No data	No data
Air	No data	No data	No data
Solubility:			
Water	517 mg/L at 37 °C <sup>c</sup>	No data	293 g/L at 0 °C
Organic Solvents	No data	No data	Insoluble in ether and acetone; 0.2 g/L at 35 °C in ethanol; 0.9 g/L at 35 °C in methanol
Partition coefficients:			
K <sub>ow</sub>	No data	No data	No data
K <sub>oc</sub>	No data	No data	No data
Vapor pressure	No data	No data	No data
Henry's law constant	No data	No data	No data
Autoignition temperature	No data	No data	Nonflammable
Flashpoint	No data	No data	Nonflammable
Flammability limits	No data	No data	Nonflammable
Conversion factor	No data	No data	No data
Explosive limits	No data	No data	No data

<sup>a</sup>All information obtained from HSDB 2004 except where noted.

<sup>b</sup>Decomposes before melting.

<sup>c</sup>Ishimatsu et al. 1995

<sup>d</sup>Data are for the hexahydrate.

<sup>e</sup>IARC 1990

<sup>f</sup>Data are for the tetrahydrate.

<sup>g</sup>Laschelles and Nicholls 1991