

4. CHEMICAL AND PHYSICAL INFORMATION

4.1 CHEMICAL IDENTITY

Lead is a naturally occurring element and is a member of Group 14 (IVA) of the periodic table. Natural lead is a mixture of four stable isotopes, ^{208}Pb (51–53%), ^{206}Pb (23.5–27%), ^{207}Pb (20.5–23%), and ^{204}Pb (1.35–1.5%). Lead isotopes are the stable decay product of three naturally radioactive elements: ^{206}Pb from uranium, ^{207}Pb from actinium, and ^{208}Pb from thorium.

Lead is not a particularly abundant element, but its ore deposits are readily accessible and widely distributed throughout the world. Its properties, such as corrosion resistance, density, and low melting point, make it a familiar metal in pipes, solder, weights, and storage batteries. The chemical identities of lead and several of its compounds are given in Table 4-1.

4.2 PHYSICAL AND CHEMICAL PROPERTIES

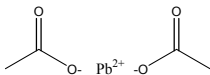
Lead exists in three oxidation states: Pb(0), the metal; Pb(II); and Pb(IV). In the environment, lead primarily exists as Pb(II). Pb(IV) is only formed under extremely oxidizing conditions and inorganic Pb(IV) compounds are not found under ordinary environmental conditions. While organolead(II) compounds are known, organolead chemistry is dominated by the tetravalent (+4) oxidation state. Metallic lead, Pb(0) exists in nature, but its occurrence is rare.

Lead's extensive use is largely due to its low melting point and excellent corrosion resistance in the environment. When exposed to air and water, films of lead sulfate, lead oxides, and lead carbonates are formed; these films act as a protective barrier that slows or halts corrosion of the underlying metal. Lead is amphoteric, forming plumbous and plumbic salts in acid and plumbites and plumbates in alkali. Lead is positioned slightly above hydrogen in the electromotive series and therefore should theoretically replace hydrogen in acids. However, the potential difference is small and the high hydrogen overvoltage prevents replacement (King and Ramachandran 1995; Sutherland and Milner 1990).

Data on the physical and chemical properties of lead and several of its compounds are given in Table 4-2.

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Table 4-1. Chemical Identity of Lead and Compounds

| Characteristic | Lead ^a | Lead acetate ^a | Lead azide ^b | Lead bromide ^c |
|---------------------------------|------------------------------------|---|----------------------------------|--------------------------------|
| Synonyms | Lead metal; plumbum; pigment metal | Lead(2+) acetic acid; plumbous acetate | Lead (2+) azide; Lead diazide | Lead (II) bromide ^d |
| Trade name | CI77575 | Salt of Saturn; sugar of lead; Unichem PBA | RD 1333 | No data |
| Chemical formula | Pb | C ₄ H ₆ O ₄ Pb | N ₆ Pb | Br ₂ Pb |
| Chemical structure ^e | Pb |  | Pb(N ₃) ₂ | PbBr ₂ |
| Identification numbers: | | | | |
| CAS registry | 7439-92-1 | 301-04-2 | 13424-46-9 | 10031-22-8 |
| NIOSH RTECS | OF7525000 ^b | AI5250000 ^b | OF8650000 | No data |
| EPA hazardous waste | D008 | U144, D008 | No data | No data |
| OHM/TADS | 7216776 | 7217255 | No data | No data |
| DOT/UN/NA/IMCO shipping | NA | UN 1616, IMO 6.1 | UN 0129 | No data |
| HSDB | 231 | 1404 | No data | No data |
| NCI | No data | No data | No data | No data |

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Table 4-1. Chemical Identity of Lead and Compounds

| Characteristic | Lead chloride ^a | Lead chromate ^a | Lead fluoroborate ^a | Lead iodide ^a |
|---------------------------------|--|--|---|---|
| Synonyms | Lead(2+) chloride; lead (II) chloride; plumbous chloride | Chromic acid (H ₂ CrO ₄) lead(2+) salt; lead chromate (VI); Yellow 34 | Borate(1-), tetrafluoro, lead(2+); lead borofluoride; lead boron fluoride; lead tetrafluoroborate | Lead diiodide; lead(II) iodide; plumbous iodide |
| Trade name | No data | Canary Chrome Yellow 40-2250; Cologne Yellow; King's Yellow | No data | No data |
| Chemical formula | Cl ₂ Pb | CrO ₄ Pb | B ₂₄ F ₈ Pb | I ₂ Pb |
| Chemical structure ^e | PbCl ₂ | PbCrO ₄ | Pb(BF ₄) ₂ | PbI ₂ |
| Identification numbers: | | | | |
| CAS registry | 7758-95-4 | 7758-97-6 | 13814-96-5 | 10101-63-0 |
| NIOSH RTECS | OF9450000 ^b | GB2975000 ^b | ED2700000 ^b | OG1515000 ^b |
| EPA hazardous waste | No data | D007, D008 | D008 | D008 |
| OHM/TADS | 7217256 | No data | 7217378 | No data |
| DOT/UN/NA/IMCO shipping | NA 2291 | No data | NA 2291; 1MO 6.1 | NA 2811 |
| HSDB | 6309 | 1650 | 1991 | 636 |
| NCI | No data | No data | No data | No data |

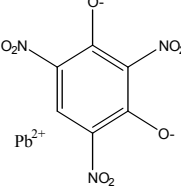
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Table 4-1. Chemical Identity of Lead and Compounds

| Characteristic | Lead molybdenum chromate ^b | Lead nitrate ^a | Lead oxide ^a |
|---------------------------------|--|--|--|
| Synonyms | Chromic acid, lead and molybdenum salt; molybdenum-lead chromate; molybdenum orange; Scarlet chrome; Red 104 | Lead dinitrate; nitric acid lead(2+) salt; lead (II) nitrate; plumbous nitrate | Lead(2+) oxide; lead oxide, yellow lead monoxide; litharge; massicot |
| Trade name | C.I. Pigment Red 104 | No data | CI 77577; CI Pigment Yellow 46 |
| Chemical formula | CRMoOPb | N ₂ O ₆ Pb | OPb |
| Chemical structure ^e | No data | Pb(NO ₃) ₂ | PbO |
| Identification numbers: | | | |
| CAS registry | 12709-98-7 | 10099-74-8 | 1317-36-8 |
| NIOSH RTECS | OG1625000 | OG2100000 ^b | OG1750000 ^b |
| EPA hazardous waste | No data | D008 | D008 |
| OHM/TADS | No data | 7217257 | No data |
| DOT/UN/NA/IMCO shipping | No data | UN 1469, IMO 5.1 | No data |
| HSDB | No data | 637 | 638 |
| NCI | No data | No data | No data |

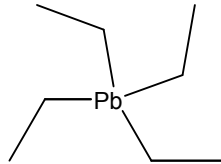
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Table 4-1. Chemical Identity of Lead and Compounds

| Characteristic | Lead phosphate ^a | Lead styphnate ^f | Lead sulfate ^a |
|---------------------------------|---|---|---|
| Synonyms | Lead(2+) phosphate; phosphoric acid lead(2+) salt | 1,3-benzenediol, 2,4,6- trinitro, lead (2+) salt (1:1); resorcinol, 2,4,6-trinitro; lead (2+) salt (1:1); lead (II) styphnate | Sulfuric acid lead(2+) salt; lead (II) sulfate |
| Trade name | Perlex Paste 500; Perlex Paste 600A; CI 77622 | No data | CI 77630; Fast White; Lead Bottoms; Mulhouse White |
| Chemical formula | O ₈ P ₂ Pb ₃ | C ₆ H ₃ N ₃ O ₈ ·Pb | O ₄ PbS |
| Chemical structure ^e | Pb ₃ (PO ₄) ₂ |  | PbSO ₄ |
| Identification numbers: | | | |
| CAS registry | 7446-27-7 | 15245-44-0 | 7446-14-2 |
| NIOSH RTECS | OG3675000 ^b | No data | OG4375000 ^b |
| EPA hazardous waste | D008, U145 | No data | No data |
| OHM/TADS | No data | No data | No data |
| DOT/UN/NA/IMCO shipping | No data | No data | UN 1794; NA 1794; IMO 8.0 |
| HSDB | 2637 | No data | 6308 |
| NCI | No data | No data | No data |

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Table 4-1. Chemical Identity of Lead and Compounds

| Characteristic | Lead sulfide ^a | Tetraethyl lead ^a | Lead carbonate ^a |
|---------------------------------|---|--|------------------------------------|
| Synonyms | Lead monosulfide; lead(2+) sulfide; Lead (II) sulfide; plumbous sulfide; natural galena | Lead, tetraethyl; TEL; tetraethyllead; tetraethylplumbane | Carbonic acid lead salt; cerussite |
| Trade name | No data | No data | No data |
| Chemical formula | PbS | C ₈ H ₂₀ Pb | PbCO ₃ |
| Chemical structure ^e | PbS |  | PbCO ₃ |
| Identification numbers: | | | |
| CAS registry | 1314-87-0 | 78-00-2 | 598-63-0 |
| NIOSH RTECS | OG4550000 | TP4550000 | OF9275000 |
| EPA hazardous waste | D008 | P110; D008 | D008 |
| OHM/TADS | 7800071 | 7216922 | No data |
| DOT/UN/NA/IMCO shipping | NA 2291; IMO 6.1 | NA 1649; IMO 6.1 | No data |
| HSDB | 639 | 841 | 1649 |
| NCI | No data | C54988 | No data |

^aHSDB 2007^bRTECS 2007^cLewis 1993^dLenga 1988^eChemIDplus 2005^fEPA 2006

CAS = Chemical Abstracts Services; DOT/UN/NA/IMO = 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; 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

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Table 4-2. Physical and Chemical Properties of Lead and Compounds

| Property | Lead ^a | Lead acetate ^a | Lead azide ^b | Lead bromide ^b |
|---------------------------------|---------------------------|--|---------------------------|-------------------------------------|
| Molecular weight | 207.20 | 325.28 | 291.25 | 367.04 |
| Color | Bluish-gray | White | White | White |
| Physical state | Solid | Solid | Needles or powder | Crystalline powder |
| Melting point | 327.4 °C | 280 °C | No data | 373 °C |
| Boiling point | 1,740 °C | Decomposes above 200 °C | Explodes at 350 °C | 916 °C |
| Density at 20 °C | 11.34 g/cm ³ | 3.25 g/cm ³ | No data | 6.66 g/cm ³ ^d |
| Odor | None | Slightly acetic | 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 at 25 °C | Insoluble | 443,000 mg/L at 520 °C | 230 mg/L at 18 °C | 8,441 mg/L at 20 °C |
| Nitric acid | Soluble | No data | No data | No data |
| Hot conc. sulfuric acid | Soluble | No data | No data | No data |
| Organic solvents | Insoluble | Soluble in glycerol, very slight in alcohol | Acetic acid ^c | Insoluble in alcohol |
| Partition coefficients: | | | | |
| Log K _{ow} | No data | No data | No data | No data |
| Log K _{oc} | No data | No data | No data | No data |
| Vapor pressure | 1.77 mmHg at 1,000 °C | No data | No data | 1 mm Hg at 513 °C |
| Henry's law constant | No data | No data | No data | No data |
| Autoignition temperature | No data | No data | No data | No data |
| Flashpoint | No data | No data | No data | No data |
| Flammability limits | No data | No data | Not flammable | No data |
| Conversion factors ^j | Not relevant ^e | Not relevant ^e | Not relevant ^e | Not relevant ^e |
| Explosive limits | No data | Lead acetate-lead bromate double salt is explosive | No data | No data |
| Valence state | 0 ^f | +2 | +2 | +2 |

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Table 4-2. Physical and Chemical Properties of Lead and Compounds

| Property | Lead chloride ^a | Lead chromate ^a | Lead fluoroborate ^b | Lead iodide ^a |
|--------------------------|-----------------------------------|--|------------------------------------|-----------------------------------|
| Molecular weight | 278.11 | 323.19 | 380.81 | 461.01 |
| Color | White | (Orange-)yellow | Colorless | Bright or golden yellow |
| Physical state | Solid | Solid | Crystalline powder | Hexagonal crystals; powder |
| Melting point | 501 °C | 844 °C | No data | 402 °C |
| Boiling point | 950 °C | Decomposes ^c | No data | Decomposes at 872 °C |
| Density at 20 °C | 5.85 g/cm ³ | 6.12 g/cm ³ at 15 °C | 1.75 g/cm ³ | 6.16 g/cm ³ |
| Odor | No data | Faint odor (solution) | Odorless | No data |
| Odor threshold | No data | No data | No data | No data |
| Solubility: | | | | |
| Water at 25 °C | 9,900 mg/L at 20 °C | 0.2 mg/L | No data | 630 mg/L at 20 °C |
| Nitric acid | No data | Soluble in dilute acid | No data | No data |
| Hot conc. sulfuric acid | No data | No data | No data | No data |
| Organic solvents | Insoluble in alcohol ^c | Insoluble in acetic acid | Decomposes in alcohol ^c | Insoluble in alcohol ^b |
| Partition coefficients: | | | | |
| Log K _{ow} | No data | No data | No data | No data |
| Log K _{oc} | No data | No data | No data | No data |
| Vapor pressure | 1 mm Hg at 547 °C | No data | No data | 1 mm Hg at 479 °C |
| Henry's law constant | No data | No data | No data | No data |
| Autoignition temperature | No data | No data | No data | No data |
| Flashpoint | No data | No data | No data | No data |
| Flammability limits | No data | Flammable with combustible organic or other oxidizable materials | Not ignited readily | Not flammable |
| Conversion factors | Not relevant ^e | Not relevant ^e | Not relevant ^e | Not relevant ^e |
| Explosive limits | No data | No data | No data | No data |
| Valence state | +2 | +2 | +2 | +2 |

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Table 4-2. Physical and Chemical Properties of Lead and Compounds

| Property | Lead molybdenum chromate ^a | Lead nitrate ^a | Lead oxide ^a |
|--------------------------|---------------------------------------|--|---|
| Molecular weight | 886.26 ^g | 331.21 | 223.20 |
| Color | No data | Colorless or white | Reddish-yellow; yellow (above 489 °C) |
| Physical state | No data | Solid | Solid |
| Melting point | No data | Decomposes at 470 °C | 888 °C |
| Boiling point | No data | No data | Decomposes at 1,472 °C |
| Density at 20 °C | No data | 4.53 g/cm ³ | 9.3 g/cm ³ (Litharge); 8.0 g/cm ³ (Massicot) ^d |
| Odor | No data | Odorless | No data |
| Odor threshold: | No data | No data | No data |
| Solubility: | | | |
| Water at 25 °C | No data | 376,500 mg/L at 0 °C 565,000 mg/L at 20 °C | 17 mg/L at 20 °C |
| Nitric acid | No data | Insoluble | Soluble (Litharge) |
| Hot conc. sulfuric acid | No data | No data | No data |
| Organic solvents | No data | 1 g in 2,500 mL absolute alcohol; 1 g in 75 mL absolute alcohol | Soluble in alkali chlorides; soluble in alkali (Massicot); insoluble in alcohol |
| Partition coefficients: | | | |
| Log K _{ow} | No data | No data | No data |
| Log K _{oc} | 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 | No data |
| Flashpoint | No data | No data | No data |
| Flammability limits | No data | Fire risk with organics | Not readily ignited |
| Conversion factors | Not relevant ^e | Not relevant ^e | Not relevant ^e |
| Explosive limits | No data | Explosive with easily oxidizable substances, and lead nitrate-lead hypophosphite double salt | 2B3 drops 90% peroxyformic acid causes violent explosion |
| Valence state | +2 | +2 | +2 |

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Table 4-2. Physical and Chemical Properties of Lead and Compounds

| Property | Lead phosphate ^a | Lead styphnate ^h | Lead sulfate ^a |
|-----------------------------|--|--------------------------------|---------------------------|
| Molecular weight | 811.54 | 450.29 ^g | 303.26 |
| Color | White | Orange-yellow (monohydrate) | White |
| Physical state | Solid | Monoclinic crystals | Solid |
| Melting point | 1,014 °C | No data | 1,170 °C |
| Boiling point | No data | No data | No data |
| Density at 20 °C | 6.9B7.3 g/cm ^{3 d} | No data | 6.2 g/cm ^{3c} |
| Odor | No data | No data | No data |
| Odor threshold: | No data | No data | No data |
| Solubility: | | | |
| Water at 25 °C | 0.14 mg/L at 20 °C | Insoluble | 42.5 mg/L |
| Nitric acid | Soluble | No data | More than in water |
| Hot conc. sulfuric acid | No data | No data | Slightly soluble |
| Organic solvents | Soluble in fixed alkali hydroxides; insoluble in alcohol | No data | Insoluble in alcohol |
| Partition coefficients: | | | |
| Log K _{ow} | No data | No data | No data |
| Log K _{oc} | 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 | No data |
| Flashpoint | No data | No data | No data |
| Flammability limits | No data | Detonates at 260 °C | Not flammable |
| Conversion factors | Not relevant ^e | Not relevant ^e | Not relevant |
| Explosive limits | No data | No data | No data |
| Valence state | +2 | +2 | +2 |

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Table 4-2. Physical and Chemical Properties of Lead and Compounds

| Property | Lead sulfide ^a | Tetraethyl lead ^a | Lead carbonate ^a |
|--------------------------|--|---|----------------------------------|
| Molecular weight | 239.27 | 323.45 | 267.2 |
| Color | Black, blue, or silvery | Colorless | Colorless rhombic crystals |
| Physical state | Cubic or metallic crystals; powder | Oily liquid | Solid |
| Melting point | 1,114 °C | No data | 315 °C (decomposes) |
| Boiling point | Sublimes at 1,281 °C | 200 °C; 227.7 °C (with decomposition) | No data |
| Density at 20 °C | 7.57–7.59 g/cm ³ | 1.653 g/cm ³ | 6.6 g/cm |
| Odor | No data | No data | No data |
| Odor threshold: | No data | No data | No data |
| Solubility: | | | |
| Water at 25 °C | 0.86 mg/L at 13 °C | 0.29 mg/L | 1.1 mg/L |
| Nitric acid | Soluble | No data | Soluble |
| Hot conc. sulfuric acid | Soluble (in acid) | No data | Soluble |
| Organic solvents | Nitric acid, hot diluted hydrochloric acid ^b ; insoluble in alcohol | Benzene, ethanol, diethyl ether, gasoline petroleum ether | Insoluble in ammonia and alcohol |
| Partition coefficients: | | | |
| Log K _{ow} | No data | 4.15 | No data |
| Log K _{oc} | No data | No data | No data |
| Vapor pressure | 10 mmHg at 975 °C | 0.26 mm Hg at 25 °C | No data |
| Henry's law constant | No data | No data | No data |
| Autoignition temperature | No data | No data | No data |
| Flashpoint | No data | 93 °C (closed cup); 85 °C (open cup) | No data |
| Flammability limits | Noncombustible | 1.8% | Not flammable |
| Conversion factors | Not relevant | Not relevant | Not relevant |
| Explosive limits | No data | Potentially, above 80 °C | No data |
| Valence state | +2 | +4 | +2 |

^aHSDB 2007^bBudavari et al. 1989^cLide 1996^dTemperature not specified.^eSince these compounds exist in the atmosphere in the particulate state, their concentrations are expressed as µg/m³ only.^fHowe 1981^gMolecular weight calculated from atomic weights.^hLewis 1993