

CHAPTER 4. CHEMICAL AND PHYSICAL INFORMATION

4.1 CHEMICAL IDENTITY

Pb is a naturally occurring element with an abundance of 0.0016% in the earth's crust (Davidson et al. 2014). It is a member of Group 14 (IVA) of the periodic table. Natural Pb is a mixture of four stable isotopes: ^{204}Pb (1.4%), ^{206}Pb (24.1%), ^{207}Pb (22.1%), and ^{208}Pb (52.4%). The Pb isotopes ^{206}Pb , ^{207}Pb , and ^{208}Pb are the stable decay product of the naturally occurring decay series of uranium, actinium, and thorium, respectively (Haynes 2014).

Pb is found in concentrated and easily accessible Pb ore deposits that are widely distributed throughout the world (King et al. 2014). 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 Pb and several of its compounds are provided in Table 4-1.

Table 4-1. Chemical Identity of Lead and Compounds

Characteristic	Lead	Lead(II) acetate	Lead(II) azide	Lead(II) bromide
Synonym(s) and registered trade name(s)	C.I. 77575; C.I. Pigment metal 4; Glover; Lead flake; Lead S2; Omaha; Omaha & Grant; SI; SO ^a	Acetic acid lead(2+) salt (2:1); neutral lead acetate; plumbous acetate; normal lead acetate; sugar of lead; salt of Saturn ^b	Lead azide ^b	Lead bromide (PbBr ₂); plumbous bromide ^b
Chemical formula	Pb ^b	Pb(CH ₃ CO ₂) ₂ ^b	Pb(N ₃) ₂ ^b	PbBr ₂ ^b
Chemical structure	Not applicable	Not applicable	Not applicable	Not applicable
CAS Registry Number	7439-92-1 ^b	301-04-2 ^b	13424-46-9 ^b	10031-22-8 ^b

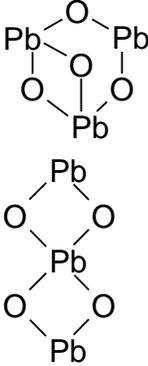
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Table 4-1. Chemical Identity of Lead and Compounds

Characteristic	Lead(II)			
	Lead(II) chloride	Lead(II) chromate	tetrafluoroborate ^c	Lead(II) iodide
Synonym(s) and registered trade name(s)	Lead chloride (PbCl ₂); Lead(2+) chloride; Plumbous chloride ^b	Chromic acid (H ₂ CrO ₄ lead(2+) salt (1:1); Chrome yellow; Cologne yellow; King's yellow; Leipzig yellow; Paris yellow; C.I. Pigment Yellow 34; lead chromium oxide (PbCrO ₄); plumbous chromate; C.I. 77600 ^b	Tetrafluoro borate(1-) Lead(2+) ^a	Lead iodide (PbI ₂); Plumbous iodide ^b
Chemical formula	PbCl ₂ ^b	PbCrO ₄ ^b	Pb(BF ₄) ₂ ^a	PbI ₂ ^b
Chemical structure	Not applicable	Not applicable	Not applicable	Not applicable
CAS Registry Number	7758-95-4 ^b	7758-97-6 ^b	13814-96-5 ^a	10101-63-0 ^b

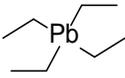
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Table 4-1. Chemical Identity of Lead and Compounds

Characteristic	Lead molybdenum chromate	Lead(II) nitrate	Lead(II) oxide	Lead(II,II,IV) oxide
Synonym(s) and registered trade name(s)	Chromic acid, lead and molybdenum salt; chromic acid lead salt with lead molybdate; C.I. Pigment Red 104; Lead chromate, Molybdenum-Lead chromate; Molybdenum Orange ^a	Nitric acid lead(2+) salt (2:1); Plumbous nitrate ^b	C.I. 77577; C.I. Pigment Yellow 46; Lead oxide; Lead oxide yellow; Lead protoxide; Litharge Yellow L-28; Massicot; Massicotite; Plumbous oxide; Yellow lead ocher ^a	Lead tetraoxide; Lead tetroxide; Lead oxide red; C.I. Pigment Red 105; C.I. 77578; Gold satinobre; Lead orthoplumbate; Lead oxide (3:4); Mineral Orange; Mineral Red; Paris Red; Saturn Red; Minium; Plumboplumbic oxide; Red Lead; Red Lead oxide; Trilead tetraoxide ^{d,e}
Chemical formula	No data	Pb(NO ₃) ₂ ^b	PbO ^a	Pb ₃ O ₄ ^e
Chemical structure	Not applicable	Not applicable	Not applicable	
CAS Registry Number	12709-98-7 ^a	10099-74-8 ^b	1317-36-8 ^a	1314-41-6 ^d

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Table 4-1. Chemical Identity of Lead and Compounds

Characteristic	Lead(II) phosphate	Lead(II) styphnate	Lead(II) sulfate
Synonym(s) and registered trade name(s)	C.I. 77622; Lead orthophosphate; Lead phosphate (3:2); Lead(2+) phosphate; normal lead orthophosphate; Phosphoric acid, lead(2+) salt (2:3); Plumbous phosphate; Trilead phosphate ^a	Lead trinitroresorcinate ^f	Anglesite; C.I. 77630; C.I. Pigment White 3; Fast White; Freemans White Lead; Lead bottoms; Milk white; Mulhouse White; Sulfuric acid, lead(2+) salt (1:1) ^a
Chemical formula	Pb ₃ (PO ₄) ₂ ^a	Pb(C ₆ H ₃ N ₃ O ₈) ₂ ^f	PbSO ₄ ^b
Chemical structure	Not applicable	Not applicable	Not applicable
CAS Registry Number	7446-27-7 ^a	15245-44-0 ^f	7446-14-2 ^b
Characteristic	Lead(II) sulfide	Tetraethyl lead	Lead(II) carbonate
Synonym(s) and registered trade name(s)	C.I. 77640; Galena; Natural lead sulfide; Plumbous sulfide ^a	Tetraethylplumbane; Lead tetraethyl; TEL ^b	Carbonic acid, lead(2+) salt (1:1); Cerussite; Dibasic lead carbonate; Lead(2+) carbonate; White lead ^a
Chemical formula	PbS ^a	Pb(C ₂ H ₅) ₄ ^a	PbCO ₃ ^a
Chemical structure	Not applicable		Not applicable
CAS Registry Number	1314-87-0 ^a	78-00-2 ^b	598-63-0 ^a

^aLewis 2012.^bO'Neil et al. 2013.^cStable only in aqueous solution (Haynes 2014).^dNLM 2020.^eHaynes 2014.^fBoileau et al. 2012.

CAS = Chemical Abstracts Services

4.2 PHYSICAL AND CHEMICAL PROPERTIES

Pb, a blueish-white metal with bright luster, is very soft, highly malleable, ductile, a poor conductor of electricity, and is very resistant to corrosion (Haynes 2014). A clean Pb surface will not be attacked by dry air; however, in moist air, the surface will react and become coated with a layer of lead(II) oxide (PbO). This coating may be hydrated and combine with carbon dioxide to form lead(II) carbonate (PbCO₃) (Carr et al. 2004). This protective coating of insoluble Pb compounds slows or halts corrosion of the underlying metal. Pb is rarely found in its metallic form in nature and commonly occurs as a

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mineral with sulfur or oxygen. The most important Pb mineral is galena (PbS). Other common Pb-containing minerals include anglesite (PbSO₄), cerussite (PbCO₃), and minium (Pb₃O₄) (Carr et al. 2004; Davidson et al. 2014; Haynes 2014).

Pb can exist in the 0 oxidation state in metallic Pb and in compounds as the +2 or +4 oxidation states. In the environment, Pb is primarily found in the +2 state in inorganic compounds. The chemistry of inorganic Pb compounds is generally similar to that of the Group 2(II) or alkaline earth metals. There are three common oxides of Pb: lead(II) oxide (PbO); lead(II,IV) oxide or lead tetroxide (Pb₃O₄); and lead(IV) oxide or lead dioxide (PbO₂). The +4 state is only formed under strongly oxidizing conditions. Inorganic Pb(+4) compounds are relatively unstable and would not be expected to be found under ordinary environmental conditions. Pb is amphoteric, meaning that it can react with acids and bases. In acid, Pb forms Pb(+2) (plumbous) and Pb(+4) (plumbic) salts and in basic solution, it forms plumbites (PbO₂²⁻) and plumbates (Pb(OH)₆²⁻) (Carr et al. 2004). In organolead compounds, Pb is typically in the tetravalent (+4) oxidation state (Carr et al. 2004; Haynes 2014).

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

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

Property	Lead	Lead(II) acetate	Lead(II) azide	Lead(II) bromide
Molecular weight	207.2 ^a	325.3 ^b	291.24 ^a	367.0 ^b
Color	Bluish-white, silvery, gray metal ^a	White crystals ^b	Needles or white powder ^a	White orthorhombic crystals ^b
Physical state	Solid	Solid	Solid	Solid
Melting point	327.4°C ^a	280°C ^b	Decomposes at 190°C ^c	371°C ^b
Boiling point	1,740°C ^a	Decomposes ^b	No data	892°C ^b
Density	11.34 g/cm ³ at 20°C ^a	3.25 g/cm ^{3b}	4.17 g/cm ³ at 20°C ^c	6.69 g/cm ^{3b}
Odor	No data	Slightly acetic odor (trihydrate) ^a	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	Insoluble ^d	443,000 mg/L at 20°C ^b	230 mg/L at 18°C ^a	9,750 mg/L at 25°C ^b
Acids	Soluble in dilute nitric acid ^d ; reacts with sulfuric acid ^a	Soluble in acid ^e	Freely soluble in acetic acid ^a	No data
Bases	No data	Soluble in alkali ^e	No data	No data
Organic solvents	Soluble in glycerin; slightly soluble in alcohol ^e	Slightly soluble in alcohol; freely soluble in glycerol ^d	No data	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	1.77 mmHg at 1,000°C ^a	No data	No data	0.0075 mmHg at 374°C ^b
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	No data	No data
Conversion factors	Not relevant ^f	Not relevant ^f	Not relevant ^f	Not relevant ^f
Explosive limits	No data	No data	Explodes at 350°C ^a	No data
Valence state	0	+2	+2	+2

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

Property	Lead(II) chloride	Lead(II) chromate	Lead(II) tetrafluoroborate	Lead iodide
Molecular weight	278.1 ^g	323.19 ^a	380.8 ^b	461.05 ^g
Color	White, orthorhombic needles ^g	Yellow or orange-yellow powder ^a	No data	Yellow hexagonal crystals ^g
Physical state	Solid	Solid	Stable only in aqueous solution ^b	Solid
Melting point	501°C ^g	844°C ^a	No data	402°C ^g
Boiling point	950°C ^g	No data	No data	954°C ^g
Density	5.85 g/cm ^{3g}	6.12 g/cm ^{3b}	No data	6.16 g/cm ^{3g}
Odor	No data	No data	No data	No data
Odor threshold	No data	No data	No data	No data
Solubility:				
Water	9,900 mg/L at 20°C ^g	0.2 mg/L ^a	Soluble ^b	630 mg/L at 20°C ^g
Acids	Slightly soluble in dilute hydrochloric acid ^g	Soluble in dilute nitric acid; insoluble in acetic acid ^a	No data	No data
Bases	Slightly soluble in dilute ammonia ^g	No data	No data	No data
Organic solvents	Insoluble in alcohol ^g	No data	No data	Insoluble in alcohol ^g
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	7.5 mmHg at 637°C ^b	No data	No data	0.75 mmHg at 470°C ^b
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	No data	No data
Conversion factors	Not relevant ^f	Not relevant ^f	Not relevant ^f	Not relevant ^f
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	Lead(II) nitrate	Lead(II) oxide	Lead(II,II,IV) oxide
Molecular weight	No data	331.23 ^g	223.21 ^g	685.57 ^e
Color	No data	Cubic or monoclinic colorless crystals ^g	Reddish-yellow; yellow (above 489°C) ^g	Bright red heavy powder ^a ; red tetrahedral crystals ^b
Physical state	No data	Solid	Solid	Solid
Melting point	No data	Begins to decompose above 205°C ^g	897°C (begins to sublime before melting) ^g	830°C ^b ; 500°C ^e
Boiling point	No data	No data	Decomposes at 1,472°C ^g	Decomposes between 500-530°C ^d
Density	No data	4.53 g/cm ^{3g}	9.53 g/cm ³ (Litharge) ^g ; 9.6 g/cm ³ (Massicot) ^g	8.92 g/cm ^{3b} ; 9.1 g/cm ^{3e}
Odor	No data	No data	No data	No data
Odor threshold:	No data	No data	No data	No data
Solubility:				
Water	No data	56:5 g/100 mL at 20°C ^g	50.4 mg/L at 25°C (Litharge) ^g ; 106.5 mg/L at 25°C (Massicot) ^g	Insoluble in water ^d
Acid	No data	Insoluble in concentrated nitric acid ^a	Soluble ^g	Dissolves in acetic acid or hot hydrochloric acid ^{b,g}
Base	No data	Soluble in alkali and ammonia ^g	Soluble ^g	No data
Organic solvents	No data	87.7 mg/L (43% aqueous ethanol) at 22°C ^g	Insoluble in alcohol ^a	Insoluble in alcohol ^g
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	No data	No data	0.0075 mmHg at 724°C ^b	No data
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	No data	No data
Conversion factors	Not relevant ^f	Not relevant ^f	Not relevant ^f	Not relevant ^f
Explosive limits	No data	No data	No data	No data
Valence state	+2	+2	+2	+2, +2, +4

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

Property	Lead(II) phosphate	Lead(II) styphnate	Lead(II) sulfate
Molecular weight	811.54 ^a	450.29 ^h	303.25 ^g
Color	White powder ^a	Monoclinic orange-yellow crystal (monohydrate) ^b	White, heavy, crystalline powder ^a
Physical state	Solid	Solid	Solid
Melting point	1,014°C ^a	No data	1,170°C ^g
Boiling point	No data	No data	No data
Density	6.9 g/cm ^{3a}	3.1 g/cm ³ (monohydrate); 2.9 g/cm ³ (anhydrous) ^b	6.2 g/cm ^{3g}
Odor	No data	No data	No data
Odor threshold:	No data	No data	No data
Solubility:			
Water	Insoluble ^b	Insoluble ^b	42.5 mg/L at 25°C ^g
Acid	Soluble in nitric acid ^a	No data	Soluble in concentrated acids ^g
Base	Soluble in fixed alkali hydroxides ^a	No data	Soluble in alkalis ^g
Organic solvents	Insoluble in alcohol ^a	No data	Insoluble in alcohol ^a
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	No data	No data
Conversion factors	Not relevant ^f	Not relevant ^f	Not relevant ^f
Explosive limits	No data	Detonates at 260°C ^b	No data
Valence state	+2	+2	+2

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

Property	Lead(II) sulfide	Tetraethyl lead	Lead(II) carbonate
Molecular weight	239.25 ^g	323.45 ^a	267.22 ^g
Color	Metallic black cubic crystals ^g	Colorless ^a	Colorless rhombic crystals ^g
Physical state	Solid	Liquid ^a	Solid
Melting point	1,114°C ^d	No data	315°C (decomposes) ^g
Boiling point	Sublimes at 1,281°C ^d	200 °C; 227.7°C (with decomposition) ^a	No data
Density	7.57–7.59 g/cm ^{3g}	1.653 g/cm ^{3a}	6.6 g/cm ^{3g}
Odor	No data	No data	No data
Odor threshold:	No data	No data	No data
Solubility:			
Water	124.4 mg/L 20°C ^g	0.29 mg/L ⁱ	1.1 mg/L at 20°C ^g
Acid	Soluble in nitric acid ^g	No data	Soluble ^g
Base	Insoluble in alkalies ^d	No data	Soluble in alkalies; insoluble in ammonia ^g
Organic solvents	Insoluble in alcohol ^a	Soluble in benzene, petroleum ether, gasoline; slightly soluble in alcohol ^a	Insoluble in alcohol ^g
Partition coefficients:			
Log K _{ow}	No data	4.15 ^j	No data
Log K _{oc}	No data	No data	No data
Vapor pressure	0.0075 mmHg at 705°C ^b	0.26 mmHg at 25°C ⁱ	No data
Henry's law constant	No data	No data	No data
Autoignition temperature	No data	No data	No data
Flashpoint	No data	200°F (93°C) (closed cup) ^k	No data
Flammability limits	No data	Lower flammable limit: 1.8% by volume ^k	No data
Conversion factors	Not relevant ^f	No data	Not relevant ^f
Explosive limits	No data	No data	No data
Valence state	+2	+4	+2

^aO'Neil et al. 2013.^bHaynes 2014.^cAkhavan 2004.^dLarrañaga et al. 2016.^eJacob 2012.^fSince these compounds exist in the atmosphere in the particulate state, their concentrations are expressed as µg/m³ only.^gCarr et al. 2004.^hMolecular weight calculated from atomic weights.ⁱFeldhake and Stevens 1963.^jWang et al. 1996.^kNFPA 2002.