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HANDBOOK OF SELECTED PROPERTIES
OF AIR-AND WATER-REACTIVE MATERIALS

U. S. NAVAL AMMUNITION DEPOT
CRANE, INDIANA



U. S. Naval Ammunition Depot
Crane, Indiana 47522

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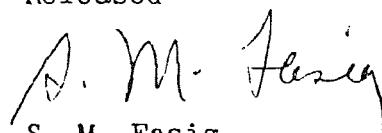
HANDBOOK OF SELECTED PROPERTIES
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by

Jack R. Gibson
Jeanne D. Weber

This report was reviewed for adequacy and technical accuracy
by William Ripley

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S. M. Fasig
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HANDBOOK OF SELECTED
PROPERTIES OF AIR- AND WATER-
REACTIVE MATERIALS

Final Report
January 1966 - December 1968

Jack R. Gibson
Jeanne D. Weber

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ABSTRACT

The Handbook of Selected Properties of Air-Reactive and Water-Reactive Materials represents the work resulting from the literature search covering the years 1950 through 1968. Data are presented on the following properties of the pertinent compounds: molecular weight, melting point, characteristics, boiling point, vapor pressure, synthesis, solubility, thermodynamic properties and flammability. In addition, attention is paid to other characteristics such as toxicity, handling and military and industrial uses.

The material is arranged in three parts: Part I. Inorganic Compounds, Part II. Organic Compounds, and Part III. Miscellaneous Compounds (analyzing complex compounds, mixtures and byproducts of chemical reactions).

F O R E W O R D

The Handbook of Selected Properties of Air-Reactive and Water-Reactive Materials was prepared under Contract PO-6-0024 by the Special Bibliographies Section, Science and Technology Division, Library of Congress.

Scope

The task consisted of searching both the open literature and unclassified reports (covering the period 1950 through 1968) for data on the properties of the pertinent compounds. The information derived from the references identified is indicated in the form of data and annotations to the individual properties.

The majority of compounds analyzed are spontaneously flammable in air, many are explosive with air and/or water. The remaining compounds are spontaneously flammable in air and water or produce smoke, and a few fit no definite category (they are spontaneously flammable only under certain circumstances or yield a spontaneously flammable compound in contact with air and/or water).

Sources Searched

In addition to the catalogs in the Library of Congress, among the important sources to the literature searched were:

Applied Science and Technology Index
ASM Review of Metal Literature
Bibliography of Chemical Reviews
Chemical Abstracts Decennial Index
Chemical Abstracts Subject Indexes
Engineering Index
Nuclear Science Abstracts
Technical Translations
U. S. Government Research Reports

Entries in the Bibliography are listed in an alpha-numeric order. No specific page indication is given for an entry cited in more than ten separate references throughout the Handbook.

Arrangement

The information on the properties of the compounds is presented alphabetically by chemical symbols on data sheets arranged in three parts:

- I. Inorganic compounds
- II. Organic compounds
- III. Miscellaneous compounds

The first two parts are further subdivided into groups of compounds. Data sheets on compounds in Part 3 are randomly arranged because of their varied chemical composition.

Attempts have been made to collect information on as many properties of the pertinent compounds as possible. These properties may range from physical and chemical characteristics through manufacturing and handling to military and industrial uses of a given compound.

Acknowledgements

The compilation of the Handbook was supervised by Dr. Clement R. Brown, Head, Special Bibliographic Section through December 1967. Bibliographic guidance was supplied by Dr. Madeleine J. Wilkins, Assistant Head, Special Bibliographies Section. Special note of appreciation is due to Mrs. Beatrice T. Treese for her invaluable contribution in preparing the Handbook for publication.

I. INORGANIC COMPOUNDS

(a) ELEMENTS

SILVER

<u>Mol. Wt.:</u> 107.87	<u>Formula:</u> Ag	
<u>M. P.:</u> 960.8°C (79)	<u>Characteristics:</u> Solid - white cubic metal (79)	<u>V. P.:</u> 101575 (79)
<u>d./sp. gr.:</u> 10.5 ²⁰ (79)	<u>B. P.:</u> 1950°C (79)	<u>$\frac{n_D}{D_s}$</u> (79) .54

Synthesis:

Prepare ultrafine powder by vacuum (less than 500 microns) evaporation and condensation (148).

Solubility:

i. alkaline solvents, hot and cold H₂O; s. HNO₃, hot H₂SO₄, KCN (79).

Flammability:

Fine powder spontaneously flammable (148).

ALUMINUM

<u>Mol. Wt.:</u> 26.9815 (79)	<u>Formula:</u> Al	
<u>M. P.:</u> 659.7°C (79)	<u>Characteristics:</u> Solid - silver colored powder, metallic, ductile (79)	
<u>d./sp. gr.:</u> 2.702 g/cm ³ (195)	<u>B. P.:</u> 2056°C (195)	<u>V.P.:</u> 11284 (195)

Toxicity:

Low, possible cause of pulmonary fibrosis (195).

Synthesis:

From purified and calcined Al₂O₃ (obtained from bauxite). It is dissolved in molten cryolite (2AlF₃·6NaF·3CaF₂) with calcium fluoride, it is kept fused by passing an electric arc between carbon electrodes, the dissolved alumina is decomposed by the electric current into aluminum and oxygen (214).

Ignition temperatures:

(80% pass through 270 mesh); 645°C (224).

Solubility:

i. cold and hot H₂O, concentrated HNO₃, hot CH₃COOH; s. alkaline solvents, HCl, H₂SO₄ (79).

Handling:

Keep aluminum powder dry, do not permit dust to filter into air, keep containers closed, do not pour from one container to another (228).

Thermodynamic properties:

heat of formation (sol): 0
heat of formation (liq): 55 kcal/mol
surface tension: 520 dynes/cm (at 750°C)
heat of fusion: 2550 cal/g atom (at 660°C)
heat of sublimation: 67497 cal/g atom (at 298, 1°K)
heat of vaporization: 65084 cal/g atom (at 298. 1K)
heat capacity: 5. 8 cal/°K (17)
thermal conductivity: 117 Btu/hr/ft²/(deg F/ft) (17)

} (177)

Military and industrial uses:

Used as pigment, aluminum based ink for printing (214).

Flammability:

Dust may explode in air, wet aluminum powder may ignite spontaneously in air (228).

BORON

Mol. Wt.:

10.811

Formula:

B

M. P.:

2300°C (179)

Characteristics:

Solid - monoclinic crystals, yellow or brown amorphous powder (79)

d. /sp. gr.:

2.34 (79)

B.P.:

2550°C (79)

Synthesis:

(1) Electrolysis of fused bath of KCl or KF and Potassium fluoroborate and boric oxide; (2) Heat boric oxides with powdered Magnesium; (3) Reduce boron halides with gas dispersion of molten alkali metal (190).

Unique conditions, reaction products:

Boron burns spontaneously in chlorine gas, ignites with heat in nitrous oxide, incandescent with fluorine, iodic acid, concentrated HNO₃, or nitrosyl fluoride (143).

Solubility:

i. cold and hot H₂O; v. sl. s. HNO₃ (79)

Thermodynamic properties:

Heat of combustion: 140 kcal/mol (199)

Military and industrial uses:

In nuclear chemistry as neutron absorber, in ignition rectifiers, and in alloys to harden other metals (132).

Flammability:

Dust ignites in air (79).

BARIUM

Mol. Wt.:

137.34

Formula:

Ba

M. P.:

850°C (79)

Characteristics:

Solid-yellow silver metal (195)

d./sp. gr.:

3.51²⁰ (79)

B.P.:

1527°C (79)

V.P.:
 10^{1049} (195)

1140°C (195)

Synthesis:

(1) $3\text{BaO} + 2\text{Al} \rightarrow 3\text{Ba} + \text{Al}_2\text{O}_3$ (repeat distillation in high vacuum) (80)

(2) $\text{Ba}(\text{N}_3)_2 \rightarrow \text{Ba} + 3\text{N}_2$ (decomposition) (80)

Solubility:

d. with evolution of H₂ in H₂O; s. alcohol; i. C₆H₆ (79)

Military and industrial uses:

Used in alloys and pyrotechnics (190).

Flammability:

Spontaneously flammable in moist air (43).

BERYLLIUM

Mol. Wt.:

9.01

Formula:

Be

M. P.:

1278 ± 5°C (79)

Characteristics:

Solid - gray, metal, hexagonal (79)

d./sp. gr.:

1.348²⁰ (79)

B.P.:

2970⁷⁶⁰ (79)

Toxicity:

Extremely toxic respiratory poison and eye irritant; threshold limit value .002 mg/m³ (142).

Synthesis:

Ultrafine powder prepared by vacuum (less than 500 microns) evaporation and condensation (148).

Unique conditions, reaction products:

Beryllium with phosphorus vapors is incandescent (143).

Solubility:

i. cold H₂O, Hg; s. dilute acid, alkaline solvent; sl. s. with d. hot H₂O (79).

Handling:

Protect from physical damage; keep dry; isolate from acids, caustics and chlorinated hydrocarbons; separate from oxidizing materials (142).

Flammability:

Powder spontaneously flammable (148).

BISMUTH

Mol. Wt.:
209.00

Formula:
Bi

M.P.:
271.3°C (195)

Characteristics:
Solid - red, hard, brittle (214)

d./sp. gr.:
9.80 (195)

B.P.:
1420-1560°C (195)

V.P.:
1¹⁰²¹ (195)

Synthesis:

Formed from decomposition of bismuth citrate in vacuo at 350°C (77).

Unique conditions, reaction products:

Powdered bismuth burns spontaneously in gaseous chlorine; ignites at 80°C with liquid chlorine; becomes red hot with fuming HNO₃ (143).

Flammability:

Spontaneously flammable (77).

CHARCOAL (Freshly calcined)

Mol. Wt.:
12.0

Formula:
C & impurities

M.P.:
>3500°C (195)

B.P.:
4200°C (195)

d./sp. gr.:
3.51 (195)

Toxicity:

Nil, except slight on inhalation (195).

Military and industrial uses:

Decolorization, filtration, metallurgical absorbent, and arc light electrode (190)

Flammability:

Spontaneously flammable in air when freshly calcined (190).

CALCIUM

Mol. Wt.:

40.08

Formula:

Ca

M. P.:

848 ± .5°C (79)

B. P.:

1240°C (79)

V.P.:
 $10^{9.83}$ (195)

d./sp. gr.:

1.54 (79)

Toxicity:

Fumes from burning calcium irritating to skin, eye and mucous membranes (195).

Synthesis:

(1) electrolysis of fused CaCl_2

(2) reduction of lime with aluminum ($3\text{CaO} + 2\text{Al} \rightarrow \text{Al}_2\text{O}_3 + 3\text{Ca}$)

(3) reduction of lime with silicon ($8\text{CaO} + 2\text{Si} \rightarrow (2\text{CaO}\cdot\text{SiO}_2) + 4\text{Ca}$)

} (132)

Unique conditions, reaction products:

Yields hydrogen on contact with H_2O (195).

Solubility:

d. in H_2O to yield $\text{H}_2 + \text{Ca}(\text{OH})_2$; s. acids, liquid NH_3 ; sl. s. alcohol; i. C_6H_6 (79)

Handling:

Store under kerosene or benzene (132); protect from physical damage, keep from water, avoid high temperatures (142).

Thermodynamic properties:

Heat of combustion: 151.7 kcal/mol (132).

Military and industrial uses:

Deoxidizer for copper, beryllium and steel; used to harden lead for bearings; used with cerium in flints (132).

Flammability:

Spontaneously flammable in air when finely divided (132).

CADMIUM

Mol. Wt.:

112.40

Formula:

Cd

M. P.:
320.9°C (79)

B.P.:
767±2°C (79)

V.P.:
 $\frac{1}{1394}$ (195)

d./sp. gr.:
8.642 (79)

n_D:
.82 (mp) (liq) (79)
1.13 (sol) (79)

Toxicity:

On ingestion causes salivation, choking, vomiting, diarrhea, and tenesmus (132).

Synthesis:

Decompose cadmium tartrate over aluminum burner, heat dried crystal tartrates until gas generation ceases, pyrophoric cadmium residue remains (76).

Unique conditions, reaction products:

Heat pyrophoric residue to 500°-600°C loses pyrophoricity (76).

Solubility:

i. hot and cold H₂O; s. acid, NH₄NO₃, hot H₂SO₄ (79)

Thermodynamic properties:

latent heat of fusion: 13.2 cal/g
latent heat of vaporization: 286.4 cal/g
electrical resistivity: 34.12 μ ohms (at 500°C)
surface tension: 598 dynes/cm (at 420°C)

} (121)

Military and industrial uses:

Used for electroplating (214).

Flammability:

Spontaneously flammable (76).

CERIUM

Mol. Wt.:
140.12

Formula:
Ce

M. P.:
815°C (79)
640°C (195)

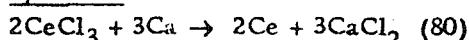
Characteristics:
Solid - steel gray crystal,
cubic or hexagonal (195)

d./sp. gr.:
6.78 (79)

B.P.:
2417°C (79)
1400°C (195)

Toxicity:

Nil, except very low on ingestion and inhalation (195).

Synthesis:Solubility:

s. d. cold H₂O; d. hot H₂O; s. dilute acid; i. alkaline solvent (79)

Military and industrial uses:

Used in: magnesium and aluminum alloys to improve mechanical properties, certain types of glass, ferro alloys for flints and pyrotechnics (58).

Flammability:

Spontaneously flammable in air at 150°-180°C (195).

COBALT

Mol. wt.:

58.933

Formula:

Co

M. P.:

1495°C (79)

Characteristics:

Solid - silver gray, metallic cubic (79)

d./sp. gr.:

8.9 (79)

B.P.:

2900°C (195)

3550°C (79)

Toxicity:

Low by oral ingestion; powder can produce dermatitis (58).

Synthesis:

(1) 2CoO(OH) + 3H₂ → 2Co + 4H₂O (reduce cobalt (III) hydroxide in porcelain boat and reduce in stream of hydrogen) (80)

(2) Add 200 ml 20% NaOH to Al(NO₃)₃·9H₂O in 300 ml H₂O, redissolve the precipitate and add a 500 ml H₂O solution of 29.1g Co(NO₃)₃·6H₂O and 20 ml concentrated HNO₃; settle, wash with H₂O, centrifuge, and dry the violet rose precipitate; grind under H₂O and boil until nitrate is absent, centrifuge and dry (80).

Unique conditions, reaction products:

Incandescent with acetylene (143).

Solubility:

i. cold and hot H₂O; s. acids (79)

Military and industrial uses:

Used in: Cobalt plating, carbide type alloys, and a bonding material for cemented Tungsten carbides (58).

Flammability:

Spontaneously flammable (80).

CHROMIUM

Mol. Wt.:
51.996

Formula:
Cr

M.P.:
 $1930 \pm 10^\circ\text{C}$ (79)

Characteristics:
Solid - steel gray, cubic,
very hard (79)

d./sp. gr.:
7.2028 (79)

B.P.:
2480°C (79)

V.P.:
11616 (79)

Synthesis:

- (1) $\text{Cr}_2\text{O}_3 + 2\text{Al} \rightarrow 2\text{Cr} + \text{Al}_2\text{O}_3$ (80)
- (2) $2\text{K}_2[\text{CrCl}_5(\text{H}_2\text{O})]_4 + 3\text{Mg} \rightarrow 2\text{Cr} + 3\text{MgCl}_2 + 4\text{KCl} + 2\text{H}_2\text{O}$ (80)

Unique conditions, reaction products:

Incandescent with nitric oxide (143); vivid incandescence with fused potassium chlorate (143);
vivid incandescence with sulfur dioxide (43).

Solubility:

i. hot and cold H_2O , HNO_3 , aqua regia; s. dilute H_2SO_4 , HCl (79)

Flammability:

Spontaneously flammable (240).

CESIUM

Mol. Wt.:
132.905

Formula:
Ce

M.P.:
 28.6°C (79)

Characteristics:
Solid - silver metallic hexagonal
crystal (79)

d./sp. gr.:
1.878515 (179)

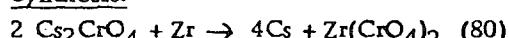
B.P.:
 $670 \pm 5^\circ\text{C}$ (79)

V.P.:
1279 (195)

Toxicity:

Pronounced physiological action, can cause hyperirritability with spasms, can cause death in animal
when in the same proportion as potassium content of diet (195).

Synthesis:



Unique conditions, reaction products:

Combines vigorously with halides at room temperature (90); with H_2O or steam yields heat and hydro-
gen (195); possible vigorous reaction with oxidizing material (195).

Solubility:

d. cold H₂O; s. liquid NH₃ (79)

Thermodynamic properties:

conductivity of liquid: 10.65 Btu/hr ft°F (216)
conductivity of vapor: .0033 Btu/hr ft°F (216)
latent heat of fusion: 6.907 Btu/lb (216)
latent heat of vaporization: 211.2 Btu/lb (216)
Resistivity: 14.36 μohm/in. (216)
Ionization potential: 3.893 volts (216)
heat of formation: 19.9 kcal/mol (90)
specific heat (liq): .0572 Btu/lb°F (216)
specific heat (vap): .0372 Btu/lb°F (216)

Military and industrial uses:

Sensitive elements in photocells, radio tubes, and ion propulsion systems (190).

Flammability:

Spontaneously flammable in moist air (195); spontaneously flammable in air at room temperature if surface is clean (143); spontaneously flammable in dry oxygen (143); at 20°C heat of reaction with water sufficient to ignite hydrogen released (143).

COPPER

Mol. Wt.:

63.54

Formula:

Cu

M. P.:

1083°C (79)

Characteristics:

Solid - red metal, cubic (79)

d./sp. gr.:

8.92 (79)

B. P.:

259°C (79)

V. P.:

11628 (195)

2324°C (195)

Synthesis:

(1) decompose copper citrate in vacuo at 350°-450°C (77); (2) vacuum (500 microns) evaporation and condensation (148); (3) from sulfide ores, concentrate roasting and forming matte - reduce the matte to crude or blister copper and reduce electrolytically (77).

Unique conditions, reaction products:

Copper foil spontaneously ignites in gaseous chlorine (143).

Solubility:

i. hot and cold H₂O; s. HNO₃, hot H₂SO₄; v. sl. s. HCl, NH₄OH (79).

Military and industrial uses:

Good conductor of heat and electricity, used for alloying with other metals (77).

Flammability:

Fine powders spontaneously flammable (148).

DEUTRIUM

Mol. Wt.:
4.032

Formula:
 D_2

Synonyms:
Heavy hydrogen

M. P.:
-254.6¹²¹ (79)

Characteristics:
Gas - colorless (79)

d./sp. gr.:
2 (79)

B. P.:
-249.7°C (79)

Synthesis:

- (1) $2D_2O + 2Na \rightarrow D_2 + 2NaOD$
(2) $D_2O + Mg \rightarrow D_2 + MgO$
(3) electrolysis of D_2O
(4) $2D_2O + U \rightarrow UO_2 + 2D_2$

} (80)

Solubility:

sl. s. cold H_2O (79)

Thermodynamic properties:

heat of fusion: 47 cal/g (132)

heat of evaporation: (at 195 mm) 302.3 cal/g (132)

Flammability:

Spontaneously flammable (27)

EUROPIUM

Mol. Wt.:
151.96

Formula:
Eu

M. P.:
1150 ± 50°C (79)

Characteristics:
Solid - steel gray metal (79)

d./sp. gr.:
5.244 (79)

Synthesis:

Reduce the oxide with lanthium or misch metal (190).

Unique conditions, reaction products:
With H_2O liberates hydrogen (190)

Solubility:

i. hot and cold H_2O (78)

Flammability:

Oxidizes rapidly in air and may burn spontaneously (190)

IRON

Mol. Wt.:
55.847

Formula:
Fe

Synonyms:
Ferrum

M. P.:
1535°C (195)

Characteristics:
Solid - silver cubic metal (79)

d./sp. gr.:
7.86 (79)

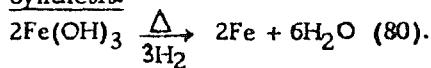
B. P.:
3000°C (195)

V. P.:
11787 (195)

Toxicity:

Nil, except very low on inhalation; threshold limit 15 mg/m³ as oxide; iron dust can cause conjunctivitis, chorioiditis and/or retinitis. Iron ore dust can cause palpebral conjunctivitis; iron oxide fumes from welding can cause chronic bronchitis with continued exposure over 30 mg/m³; fresh iron oxide fumes can cause metal fume fever (195).

Synthesis:



Unique conditions, reaction products:

Incandescent reaction with ClF₃ (143).

Ignition temperature:

(99 through 270 mesh): 320°C (224).

Solubility:

i. hot and cold H₂O; s. acids, alkaline solvents, alcohol, ether (79)

Flammability:

Pyrophoric powder produced from Fe(OH)₃ if reduction temperature is lower than 550°C (80)

HAFNIUM

Mol. Wt.:
178.49

Formula:
Hf

M. P.:
2330°C (79)

Characteristics:
Solid - hexagonal (79)

d./sp. gr.:
13.31 (79)

B. P.:
>3200°C (79)

Synthesis:

Thermal decomposition of its iodide, reduction of the tetrachloride or of the hydro-fluorohafnide with metallic sodium; reduction of the oxide with a mixture of calcium and sodium (132).

Ignition temperature:

Dust cloud: 20°C (68°F) (80)

Solubility:

s. Hf; i. hot and cold H₂O (79)

Flammability:

Spontaneously flammable (213)

POTASSIUM

Mol. Wt.:

39.102

Formula:

K

Synonyms:

Kallium

M.P.:

62.3°C (79)

Characteristics:

Solid - silver cubic metal (79)

d./sp. gr.:

.86²⁰ (79)

B.P.:

760°C (79)

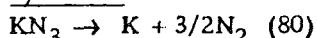
V.P.:

1³⁴¹ (195)

Toxicity:

High as irritant, on ingestion and on inhalation (195).

Synthesis:



Unique conditions, reaction products:

Yields KOH + H₂ in reaction with H₂O; potassium melts and spatters and releases sufficient heat to ignite H₂ released, if confined may have explosion; potassium metal will form K₂O₂ and KO₂ or K₂O₄ at room temperature even if stored under mineral oil; may explode if handled or cut (195); ignites spontaneously in dry Cl, F and NO₂, is incandescent with CHO₃ and Na₂O₂ (143).

Solubility:

d. to KOH in hot or cold H₂O; d. alcohol; s. acid, Hg, NH₃ (79).

Handling:

Store in inert atmosphere or under O₂ free liquid or in vacuum glass capsules, keep in detached fireproof buildings, do not heat in glass to melting point of potassium or a violent reaction with the glass takes place, dispose of by allowing small pieces to react with moisture in air and turn to potassium hydroxide (195).

Thermodynamic properties:

latent heat of vaporization: 496 cal/g (122)

heat of combustion: 43 kcal/mol (1,980 Btu/lb) (199)

Military and industrial uses:

Used in: synthesis of inorganic potassium compounds; in organic synthesis involving condensation, dehalogenation, reduction and polymerization reactions; used as heat transfer medium with sodium (132).

Flammability:

Can ignite spontaneously in moist air and burn, may explode (195).

LITHIUM

Mol. Wt.:
6.939

Formula:
Li

M. P.:
179°C (79)

Characteristics:
Solid - soft silver white (79)

d./sp. gr.:
.534²⁰ (79)

B.P.:
1317°C (79)

V.P.:
172³ (79)

Toxicity:

Slight, very caustic in H₂O (195).

Synthesis:

- (1) LiBr electric arc \rightarrow Li + 1/2 Br₂ (80)
- (2) Electrolysis of fused mixture of LiCl and KCl (108)
- (3) Reduce oxide with magnesium or aluminum (108)

Ignition temperature:

Autoignition temperature (in air): 180°C (143).

Solubility:

d. cold H₂O (79); dissolves (with evolution of H₂) in dilute HCl or H₂SO₄ (132); s. liquid NH₃ (132).

Handling:

Protect from physical damage; avoid H₂O, high temperatures and halogenated hydrocarbons (142); immerse in inert O₂ free solvent (108).

Thermodynamic properties:

heat of fusion: 1,100 cal/mol
heat of vaporization: 32,300 cal/g mol } (108)
heat capacity (at 25°C): .814 cal/g°C }
electrical resistivity: 45.25 μ ohms (at 230°C) (121)

Military and industrial uses:

Possible use as propellant (108).

Flammability:

Spontaneously flammable in air (142).

MAGNESIUM

Mol. Wt.:
24. 312

Formula:
Mg

M. P.:
651°C (79)

Characteristics
Solid - silver white hexagonal metal (79)

d. sp. gr.:
1. 745 (79)

B.P.:
1170°C (79)

V.P.:
1621 (195)

Toxicity:

Injurious if embedded in skin; irritant to respiratory tract (132).

Unique conditions, reaction products

Spontaneously flammable with moist Fe and Cl; powdered Mg is incandescent with boron phosphide and explodes with chloroform or methyl chloride (143).

Ignition temperature:

(86% passes through 270 mesh) 570°C (224).

Solubility:

i. cold H₂O, CrO₂, alkaline solvents; d. to Mg(OH)₂ in hot H₂O; s. mineral acids, concentrated HF, ammonium salts (79).

Handling:

Store away from oxidizing agents, protect from static electricity, keep containers grounded, and handle carefully (229).

Thermodynamic properties:

heat of formation (vap): 35.907 cal/mol (at 298.1°C) (180)

heat of formation (sol): 0 (180)

dipole moment: 0 debye (180)

heat of fusion: 2. 160 cal/mol (180)

heat of vaporization: 32,517 kcal/g atom (at 1107°C and 760 mm) (180)

heat of combustion: -146,100 cal/mol (181)

critical temperature: 2100°C (181)

electrical conductivity: 38.6 (132)

specific heat: 249 cal/g (132)

Military and industrial uses:

Used in light alloys, in the manufacture of precise instruments, in pyrotechnics, flash bulbs, and flares (132).

Flammability:

Fine powder dissipated in air presents dangerous fire and explosion hazard (229).

MANGANESE

<u>Mol. Wt.:</u>	<u>Formula:</u>	
54.93	Mn	
<u>M. P.:</u>	<u>Characteristics:</u>	
1212°C (79)	Solid - grayish pink cubic or tetragonal metal (79)	
<u>d./sp. gr.:</u>	<u>B.P.:</u>	<u>V.P.:</u>
7.44 (79)	2152°C (79)	11282 (79)

Toxicity:

Maximum allowable concentration is 5 mg/m³, high chronic systemic on inhalation; moderate acute systemic on inhalation (195).

Synthesis:

Electrolyze MnSO₄·4H₂O + (NH₄)₂SO₄ distill manganese prepared in this fashion, place in Al₂O₃ boat, establish a vacuum of at least .005 mmHg, heat to 1250-1350°C, distill metal deposits as small needles on a tubular nickel sleeve cooled by H₂O (cold) (80).

Unique conditions, reaction products:

Powdered manganese ignites and burns brilliantly in Cl, incandesces with F, incandesces and feebly explodes with HNO₃, ignites in NO₂ (143).

Ignition temperature:

(63% can pass through 270 mesh): 450°C (40)

Solubility:

d. cold and hot H₂O; s. dilute acids (79)

Thermodynamic properties:

specific heat: 115 cal/g (132)

latent heat of fusion: 63.7 cal/g (132)

Flammability:

Product of synthesis extremely reactive and ignites upon exposure to air (80).

MOLYBDENUM

<u>Mol. Wt.:</u>	<u>Formula:</u>	
95.94	Mo	
<u>M. P.:</u>	<u>Characteristics:</u>	
2620 ± 10°C (79)	Solid - silvery white metal to grayish black cubic powder (79)	
<u>d./sp. gr.:</u>	<u>B.P.:</u>	<u>V.P.:</u>
10.2 (79)	4057°60 (79)	13102 (195)

Synthesis:

- (1) $\text{MoO}_3 + 3\text{H}_2 \rightarrow \text{Mo} + 3\text{H}_2\text{O}$ (80)
(2) $3\text{MoO}_2 + 4\text{Al} \rightarrow 3\text{Mo} + 2\text{Al}_2\text{O}_3$ (80)

Unique conditions, reaction products:

Incandescent reaction with ClF_3 , F, and PbO_2 (143).

Solubility:

i. hot and cold H_2O ; s. hot concentrated HNO_3 , hot concentrated H_2SO_4 , aqua regia, HF and NH_3 ; sl. s. HCl (79)

Flammability:

Spontaneously flammable (240).

SODIUM

Mol. Wt.:

22.9898

Formula:

Na

Synonyms:

Natrium

M. P.:

97.5°C (79)

Characteristics:

Solid - silvery cubic metal (79)

d./sp. gr.:

.9720 (79)

B.P.:

883°C (79)

V.P.:

1.2⁴⁰⁰ (195)

 n_D^{D} :

4.22 (79)

Toxicity:

Acute local, (metallic sodium) slight irritant, high on ingestion and inhalation; (sodium smoke) moderate as irritant, high on ingestion, reacts exothermally with moisture of body or tissue surface causing thermal and chemical burns (195).

Synthesis:

- (1) $2\text{Na}_2\text{MoO}_4 + \text{Zr} \rightarrow 4\text{Na} + \text{Zr}(\text{MoO}_4)_2$ (80)
(2) $2\text{Na}_2\text{WO}_4 + \text{Zr} \rightarrow 4\text{Na} + \text{Zr}(\text{WO}_4)_2$ (80)
(3) $\text{NaN}_3 \rightarrow \text{Na} + 3/2\text{N}_2$ (80)
(4) electrolytic production from fused NaCl (190)

Ignition temperature:

Autoignition temperature: above 115°C in dry air (195).

Solubility:

d. cold H_2O to yield $\text{NaOH} + \text{H}_2$; d. alcohol; i. ether, C_6H_6 (79)

Handling:

Keep from moisture, O_2 or halides, use sufficient heat to prevent condensation (195).

Thermodynamic properties:

dipole moment μ : 0 debye
heat of formation (at 298.1°C): (sol) .0
heat of formation (at 298.1°C): (vap) -25.949 cal/mol (182)
heat of fusion: 635 cal/g atom
heat of combustion: 50 kcal/mol (3,920 Btu/lb) (190)

Military and industrial uses:

Used in the manufacture of sodium compounds, lead tetraethyl, used in organic synthesis photoelectric cells and in sodium lamps (132)

Flammability:

Violent reaction with H₂O liberating and igniting hydrogen (180).
Heated sodium spontaneously flammable in air (182).

NICKEL

Mol. Wt.:

58.71

Formula:

Ni

M.P.:

1455°C (79)

Characteristics:

Solid - silver metal,
cubic (79)

d./sp. gr.:

8.90 (79)

B.P.:

2730°C (79)

V.P.:
11810 (195)

2900°C (195)

3177°C (80)

Toxicity:

Large quantities cause nausea, vomiting, diarrhea, central nervous system depression and myocardial damage on ingestion (132).

Synthesis:

- (1) NiO + H₂ → Ni + H₂O (80)
- (2) decompose nickel oxalate in vacuo at 350°-450°C (good yield)
- (3) decompose nickel citrate in vacuo at 350°-450°C (poor yield) (71)
- (4) decompose nickel formate in vacuo at 350°-450°C (poor yield)

Solubility:

i. hot and cold H₂O, NH₃; s. dilute HNO₃; sl. s. HCl, H₂SO₄ (79)

Military and industrial uses:

Used in alloys, catalyst for hydrogenation of saponifiable oils (132).

Thermodynamic properties:

specific heat (at 100°C): .1123

latent heat of fusion: 73 cal/g (132)

Mohs' hardness: 38

Flammability:

Spontaneously flammable (80).

PHOSPHORUS
(White or Yellow)

Mol. Wt.:
123.8952

Formula:
 P_4

M.P.:
44.1°C (79)
d./sp. gr.:
1.82²⁰ (79)

Characteristics:
Solid - yellow to white cubic
or wax like (79)
B.P.:
280°C (79)

n_D:
 $\frac{2.144}{176.6}$ (79)

Toxicity:

Fumes are an irritant but only slightly toxic; keep away from skin (causes severe, difficult to handle burns) (195).

Synthesis:

Distill commercial phosphorus in CO₂ atmosphere to remove arsenic or melt white phosphorus (commercial) under dilute chromosulfuric acid, stir vigorously with glass rod and after solidification wash with distilled water (80).

Unique conditions, reaction products:

Gives off dense white smoke of phosphorous pentoxide and phosphoric acid, smoke has great obscuring power (132).

Solubility:

.0003¹⁵ H₂O; sl. s. hot H₂O; .3 alcohol; 880¹⁰ CS₂; s. C₆H₆, NH₃, alkaline solvent, ether, chlorine, C₆H₅CH₃ (79).

Handling:

Handle with forceps, keep under water (132).

Military and industrial uses:

Powerful incendiary, burning pieces adhere to skin and clothes, used by allies in World War II for screening smokes in hand grenades and mortars. Now used extensively for incendiary purposes in shells and bombs, used in matches (18); used as rat poisons, gas analysis, and with metals to form phosphides (132).

Flammability:

Spontaneously flammable in air at 34°C (79).

PHOSPHOROUS
(red)

Mol. Wt.:
123.8952

Formula:
 P_4

<u>M. P.:</u> 590 ⁴³ (79)	<u>Characteristics:</u> Solid - reddish brown cubic or amorphous powder (79)	
<u>d./sp. gr.:</u> 2.34 2.34 (79)	<u>B.P.:</u> Ignites 200°C (79)	<u>V.D.:</u> 4.77 g/cm ³ (195)

Toxicity:

Slight as irritant, moderate on ingestion (195).

Synthesis:

Formed from white phosphorus at 240°C in absence of O₂ (214).

Unique conditions, reaction products:

Explosive when mixed with oxidizing materials (195).

Ignition temperature:

Autoignition temperature 500°F (195).

Solubility:

v. sl. s. cold H₂O; i. hot H₂O, CS₂, alcohol, NH₃; s. absolute alcohol (79)

Handling:

Ship in cans or drums, protect from physical damage, store in cool place with adequate ventilation, separate from other materials (190).

Military and industrial uses:

Used in matches (214).

Flammability:

Commercial red phosphorus subject to spontaneous combustion in thick layers, critical thickness of layer defined by $Y = 2X = [K(T_0 - T_a)/Q]^{1/2}$ where Y = critical thickness of layer α in centimeters, above which spontaneous combustion occurs, X = distance in cm from plane of wax, K = heat transfer coefficient. To = autogenous temperature, Ta = ambient temperature, Q = heat of reaction in cal/cc/sec. The thickness of layer above which spontaneous combustion occurs is inversely proportional to the temperature of the rate of glueration of heat which is directly proportional to the oxidation rate of red phosphorus (212).

LEAD

<u>Mol. Wt.:</u> 207.19	<u>Formula:</u> Pb	
<u>M. P.:</u> 327.43°C (79)	<u>Characteristics:</u> Solid - silvery bluish white soft cubic metal (79)	
<u>d./sp. gr.:</u> 11.288 ²⁰ (79)	<u>B.P.:</u> 1515°C (79)	<u>V.P.:</u> 1973 (195)

Synthesis:

Decompose tartrate by heating over aluminum burner, dried crystal tartrate heated until gas generation ceases, heat beyond 500°-600°C lost pyrophoricity (76)

Solubility:

i. hot and cold H₂O; s. HNO₃, hot concentrated H₂SO₄ (79)

Thermodynamic properties:

latent heat of fusion: 5.89 cal/g
latent heat of vaporization: 204.6 cal/g
electrical resistivity: 94.6 μ ohms (at 327°C)
surface tension: 442 dynes/cm (at 350°C)

} (121)

Flammability:

Spontaneously flammable (115)

PLUTONIUM

Mol. Wt.:
242.00

Formula:
Pu

M. P.:
639.5 ± 2°C (79)

B.P.:
3235 ± 19°C (79)

Toxicity:

Highly toxic. (195).

Synthesis:

Obtained by neutron bombardment of U²³⁸ (57)

Military and industrial uses:

Nuclear-reactor fuel and product (57).

Flammability:

Chips, turnings and fine particles spontaneously ignite (56).

RUBIDIUM

Mol. Wt.:
85.47

Formula:
Rb

M. P.:
38.5°C (79)

Characteristics:
Solid - silver white soft metal (79)

d./sp. gr.:
1.532 (sol) (79)
1.475^{38.5} (liq) (79)

B.P.:
700°C (79)

V.P.:
1297 (195)

Toxicity:

Moderate (acute systemic) on ingestion; slight (chronic local, systemic) on ingestion (195).

Synthesis:

- (1) $2\text{Rb}_2\text{CrO}_4 + \text{Zr} \rightarrow 4\text{Rb} + \text{Zr}(\text{CrO}_4)_2$
 (2) $2\text{Rb}_2\text{Cr}_2\text{O}_7 + \text{Zr} \rightarrow 4\text{Rb} + \text{Zr}(\text{Cr}_2\text{O}_7)_2$
 (3) $\text{RbCl} + 1/2\text{Ca} \rightarrow 1/2 \text{CaCl}_2 + \text{Rb}$

} (80)

Unique conditions, reaction products:

Explosive reaction with acids and oxidizers (195)

Solubility:

d. hot and cold H_2O , alcohol; s. acids (79)

Handling:

Keep immersed in dry saturated hydrocarbon liquid or inert gas atmosphere (216).

Thermodynamic properties:

resistivity: $8.81 \mu\text{ohm/in.}$

ionization potential: 4. 126 volts

thermal conductivity (liq): $11.65 \text{ Btu/hr ft}^\circ\text{F}$

thermal conductivity (vap): $.00482 \text{ Btu/hr ft}^\circ\text{F}$ } (216)

specific heat (liq): $.0877 \text{ Btu/lb}^\circ\text{F}$

specific heat (vap): $.0578 \text{ Btu/lb}^\circ\text{F}$

latent heat of fusion: 11.79 Btu/lb

latent heat of vaporization: 347.8 Btu/lb

Military and industrial uses:

Used in rubidium salts, reagent in zeolite catalysts, and in photoelectric cells (132).

Flammability:

Explosive reaction with H_2O (195); ignites spontaneously in dry air (216); heat of reaction with H_2O ignites hydrogen liberated (143).

SULFUR

Mol. Wt.:

256.512

Formula:

S_8

Synonyms:

Sulfur flour

Flowers of sulfur

Brimstone

M.P.:

α 95.5-112.8°C (79)

β 118.75°C (79)

γ about 120°C (79)

Characteristics:

α Solid - yellow rhombic (79)

β Solid - pale yellow

monoclinic (79)

γ Solid - pale yellow
amorphous

d./sp/ gr.:

α 2.07^{20} (79)

β 1.96 (79)

γ 1.92 (79)

B.P.:

α
 β } 444.6°C (79)
 γ

V.P.:
 183.8 (195)

$$\frac{n_D}{\alpha 1.957} (79)$$

Toxicity:

Very low (195).

Synthesis:

Purify commercial sulfur by repeated recrystallization from CS_2 , or boil liquid sulfur with MgO and allow to stand at 125°C overnight, filter settled black sludge through glass wool (MgO and sludge separate rapidly) treat clear filter four times in same manner (boil 25-30 hrs) cool very slowly get very pure sulfur (80).

Ignition temperature:

Flash point: 405°F . (195)

Autoignition temperature: 450°F (195)

Solubility:

i. hot and cold H_2O

$\alpha 23^\circ\text{CS}_2$; sl. s. $\text{C}_6\text{H}_5\text{CH}_3$, alcohol, C_6H_6 , ether, liquid NH_3 ; s. CCl_4

$\beta 70^\circ\text{CS}_2$; s. alcohol, C_6H_6

γ i. CS_2

} (79)

Military and industrial uses:

In H_2SO_4 , vulcanizing agent in rubber, ingredient in gunpowder, corrosion resistant cements, paper manufacture, plastics, and medicines (214).

Flammability:

Spontaneously flammable (211)

SILICON

Mol. Wt.:

28.086

Formula:

Si

M.P.:

1410°C (79)

Characteristics:

Solid - steel gray, large to micro cubic crystal (79)

d./sp. gr.:

2.32 - 2.34 (79)

B.P.:

2355°C (79)

V.P.:

11724 (79)

Unique conditions, reaction products:

Spontaneous burning in gaseous chlorine, reacts violently with AsF_3 (143).

Ignition temperature:

(86% pass through 270 mesh); 775°C (240).

Solubility:

i. hot and cold H_2O , HF; s. HF and HNO_3 (79)

Flammability:

Spontaneously flammable dust (240).

TIN

Mol. Wt.:
118.69

Formula:
Sn

M. P.:
231.9°C (195)

Characteristics:
Solid - gray cubic crystals (195)

d./sp. gr.:
5.75 (195)

B.P.:
2260°C (79)

V.P.:
11492 (195)

n_D:
(liq) 2.1 (79)

Synthesis:

Decompose tin oxalate or tin tartrate in vacuo at 350°-450°C (77).

Unique conditions, reaction products:

Tin reacts with heated chlorine to yield light and more heat; Na₂O₂ oxidizes tin to incandescence (143).

Solubility:

i. hot and cold H₂O; s. HCl, H₂SO₄, aqua regia, alkaline solvents; sl. s. HNO₃ (79)

Flammability:

Spontaneously flammable when finely divided (115).

STRONTIUM

Mol. Wt.:
87.62

Formula:
Sr

M. P.:
752°C (195)
774°C (79)

Characteristics:
Solid - silver white to pale yellow metal (79)

d./sp. gr.:
2.6²⁰ (79)

B.P.:
1366°C (79)

V.P.:
10892 (79)

Synthesis:

Sr(N₃)₂ → Sr + 3N₂ (80)

Solubility:

s. liquid NH₃, HNO₃, HCl, dilute H₂SO₄ (132)

Military and industrial uses:

Fireworks, red signal flares, tracer bullets (132).

Flammability:

If finely divided ignites on exposure to air (132).

TRITIUM

Mol. Wt.:
3.017 (27)

Formula:
 T_2

Characteristics:
Gas (27)

Military and industrial uses:
Radioactive tracer (132)

Flammability:
Spontaneously flammable (27)

THORIUM

Mol. Wt.:
232.038

Formula:
 Th

M. P.:
1845°C (79) Characteristics:
Solid - gray, cubic, radioactive (79)

d./sp. gr.:
11.7 (79) B. P.:
4230°C (79)

Toxicity:
Cause dermatitis and certain radioactive hazards (195); possible safe concentration in air .1mg/m³ (11).

Synthesis:

- (1) $ThCl_4 + 4Na \rightarrow Th + 4NaCl$ (tetrachloride reduction with sodium)
(2) $ThO_2 + 2Ca \rightarrow 2CaO + Th$ (oxide reduction)
(3) $Th(NO_3)_4 \cdot 4H_2O \rightarrow KTh.F_5 \rightarrow Th$ (electrolysis)
(4) $ThI_4 \rightarrow Th + 2I_2$ (refining process)
- } (80)

Unique conditions, reaction products:

Incandescent reaction with chlorine (143).

Ignition temperature:

(100% through 270 mesh): 270°C (240).

Solubility:

i. hot and cold H_2O ; s. HCl , H_2SO_4 , aqua regia; sl. s. HNO_3 (79).

Flammability:

Spontaneously flammable (high as powder, moderate as chips) (11).

URANIUM

Mol. Wt.:
238.03

Formula:
U

M.P.:
 $1132 \pm 1^\circ\text{C}$ (79)

Characteristics:
Solid - silver, cubic radioactive (79)

d./sp. gr.:
 $19.05 \pm .02^{25}$ (79)

B.P.:
 3818°C (79)

Toxicity:

High, radioactive, toxic when inhaled or swallowed, (chemical poison affects kidneys)
maximum acceptable concentration (ACGIH) .05 mg/m³ air (soluble uranium compounds);
.25 mg/m³ air (insoluble uranium compounds) (195).

Synthesis:

- (1) $\text{UO}_2 + 2\text{Ca} \rightarrow \text{U} + 2\text{CaO}$ (metallic calcium reduces oxide) (80)
- (2) Reduce U_3O_8 by freshly distilled calcium in high vacuum (yields very pure uranium) (80)
[$\text{CaCl}_2 + \text{BaCl}_2$ (prefused) added to reactant mixture above improves procedure] (80)
- (3) $\text{UCl}_4 + 4\text{Na} \rightarrow \text{U} + 4\text{NaCl}$ (80)
- (4) $\text{UCl}_5 + 5\text{Na} \rightarrow \text{U} + 5\text{NaCl}$ (80)

Unique conditions, reaction products:

Explosive reaction with HNO_3 ; ignites in warm NO_2 ; incandescent reaction with hot Se or S (143).

Ignition temperature:

(100% through 270 mesh): 20°C (240).

Solubility:

i. hot and cold H_2O , alkaline solvent, alcohol; s. acids (79)

Thermodynamic properties:

specific heat (at 25°): 6.65 (132)
heat of fusion: 4.7 kcal/mol (132)

Flammability:

Powder spontaneously flammable, spontaneous ignition may result in intense heat and fumes;
if dry ignites in air, if dispersed in air explodes (12).

TUNGSTEN

Mol. Wt.:
183.85

Formula:
W

Synonyms:
Wolfram

M.P.:
 3410°C (79)

Characteristics:
Solid - gray black cubic (79)

d./sp. gr.:
19.35²⁰₄ (79)

B.P.:
5900760 (79)

V.P.:
13990 (195)

Synthesis:

- (1) β tungsten is prepared by electrolysis and thermal reduction of WO_3 (194)
(2) fluoridize W in vertically rising hydrogen stream and follow by reduction of WO_3 or ammonium paratungstate to pure tungsten powder (grain growth is suppressed by yellow oxide present as suspension) (222)

Solubility:

- i. cold and hot H_2O , HF, and KOH; v. sl. s. HNO_3 , H_2SO_4 , aqua regia; s. $HNO_3 + HF$ (79)

Thermodynamic properties:

specific heat (at 20°C): .032 cal/g/ $^{\circ}C$ (132)

heat of fusion: 44 cal/g (132)

heat of vaporization: 1150 cal/g (132)

Military and industrial uses:

Increase hardness, toughness, elasticity and tensile strength of steel, manufacture alloys, filaments for incandescent lights and electron tubes, also used for contact points for automotive, telegraph, radio and TV apparatus (132).

Flammability:

β -tungsten spontaneously flammable (194)

ZINC

Mol. Wt.:
65.37

Formula:
Zn

M.P.:
419.47°C (79)

Characteristics:
Solid - bluish white hexagonal metal (79)

d./sp. gr.:
7.14 (79)

B.P.:
907760 (79)

V.P.:
1487 (195)

Toxicity:

When heated it evolves fumes which cause "brass founders ague" (195); threshold limit of fumes 15 mg/m³ (143).

Synthesis:

Decompose tartrate by heating over aluminum burner, heat dried crystal tartrates until gas generation ceases, if heat to 500°-600°C loses pyrophoricity (76).

Unique conditions, reaction products:

Evolves H_2 with alkali hydroxides (132); incandescent reaction with CS_2 , burns in moist chlorine, explodes with heat with Manganese chloride or Potassium nitrate; incandescent reaction with selenium or tellurium or Na_2O_2 (143).

Ignition temperature:

(100% through 270 mesh): 600°C (240)

Solubility:

i. hot and cold H₂O; s. acids, alkaline solvent, acetic acid (79)

Handling:

Protect from physical damage, store in cool, dry, well ventilated place, separate from acids, halogenated hydrocarbons and strong alkali hydroxides, protect from moisture (142).

Thermodynamic properties:

Mohs' hardness: 2.5 (195)

electrochemical equivalent: 1.220 g/amp hr (195)

Military and industrial uses:

Used in alloys, galvanizing iron and other metals, electroplating, fuses (electrical), and anodes (190).

Flammability:

Bulk dust in damp state may heat spontaneously and ignite on exposure to air (142).

ZIRCONIUM

Mol. Wt.:

91.22

Formula:

Zr

M. P.:

1857°C (79)

Characteristics:

Solid - silver gray metal (79)

d./sp. gr.:

6.49 (79)

B. P.:

>2900°C (79)

Toxicity:

Threshold value 5 mg/m³ air; low for acute and chronic exposures (195).

Synthesis:

- (1) ZrI₄ → Zr + 2I₂
- (2) ZrO₂ + 2Ca → Zr + 2CaO
- (3) K₂ZrF₆ + 4Na → Zr + 2KF + 4NaF (80)
- (4) ZrCl₄ + 4Na → Zr + 4NaCl
- (5) ZrCl₄ + 2Mg → Zr + 2MgCl₂

Unique conditions, reaction products:

With borax explodes when heated, explodes violently with cupric oxide, slight explosion with potassium chlorate and heat or potassium nitrate and heat (143).

Ignition temperature:

304°F (27)

Autoignition temperature: 500°F (195)

Solubility:

i. hot and cold H₂O; s. HF, aqua regia; sl. s. CH₃COOH (79)

Handling:

Ship in glass or metal containers inside wooden boxes, metal barrels. Protect from physical damage, isolate from oxidizing materials (142).

Thermodynamic properties:

Brinnel hardness : 85 (132)

Military and industrial uses:

Structural material for atomic reactors (132)

Flammability:

Powder spontaneously flammable in air (27).

(b) ALLOYS

CERIUM AMALGAM

Mol. Wt.:	Formula:
CeHg ₄ 942.57	CeHg ₄)
CeHg ₄ 541.35	CeHg ₂ } (84)
CeHg 280.26	CeHg }

Flammability:

Spontaneously flammable in air (233)

CERIUM-INDIUM ALLOYS

Mol. Wt.:	Formula:
Ce ₂ In 395.06	Ce ₂ In)
CeIn 254.94	CeIn } (235)
Ce ₂ In ₃ 624.70	Ce ₂ In ₃ }

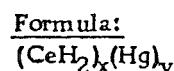
Unique conditions, reaction products:

CeIn₃ not pyrophoric (235)

Military and industrial uses:

Spontaneously flammable alloys, 0%-30% Ce alloy has the greatest pyrophoricity (235).

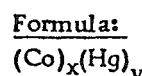
CERIUM HYDRIDE AMALGAM



Flammability:

Concentrated mixtures of CeH₃ and Hg on admission to air rapidly develop a luminous black precipitate and ignite spontaneously, black precipitate reasonably pure CeH₃; CeH₃ amalgam broken under water results in a vigorous reaction evolving H₂ and sparks (215).

COBALT AMALGAM



Characteristics:

Solid - gray to black powder (169)

Synthesis:

(1) Electrolytic reduction of cobalt by a mercury cathode forms a suspension of fine metal powder in mercury, separation of mercury by vacuum distillation yields cobalt amalgam (169); (2) react sodium amalgam and concentrated solution of cobalt chloride; (3) potassium amalgam in solution of cobaltous chloride sulphate or nitrate; react zinc amalgam in aqueous solution of cobaltous chloride saturated with ammonia (yields hydrogen) (131).

Solubility:

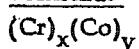
sl. d. H₂O; i. Hg (131).

Flammability:

Spontaneously flammable (169).

CHROMIUM-COBALT ALLOY

Formula:



Characteristics:

Solid - tetragonal crystals (CoCr) (131)

Unique conditions, reaction products:

Miscible in all proportions, minimum crystallization temperature is 1320°C when fused mass has 47% chromium, structural change at 1226°C with 30-100% chromium (131).

Flammability:

When smaller than 1μ are spontaneously flammable alloys (240).

CESIUM ARSENIC ALLOY

Mol. Wt.:

473. 65

Formula:



Flammability:

Spontaneously flammable (240).

CESIUM BISMUTH ALLOY

Mol. Wt.:

682. 64

Formula:



Flammability:

Spontaneously flammable (240).

Powder
react
ion
chloride

CESIUM-ANTIMONY ALLOY

<u>Mol. Wt.:</u>	<u>Formula:</u>
(Cs ₃ Sb) 595.41	Cs ₃ Sb
(Cs ₅ Sb) ₄ 487.04	Cs ₅ Sb ₄

Flammability:

Spontaneously flammable (240).

IRON AMALGAM

<u>Formula:</u>
(Fe) _x (Hg) _y

Characteristics:

Solid - gray to black powder (169)

Synthesis:

Electrolytic reduction of iron by a mercury cathode forms a suspension of fine metal powder in mercury, separation of mercury by vacuum distillation yields iron amalgam (169).

Flammability:

Spontaneously flammable (169).

POTASSIUM ARSENIC ALLOY

<u>Formula:</u>
(K) _x (As) _y

Flammability:

Spontaneously flammable (240).

POTASSIUM-PHOSPHORUS ALLOY

<u>Mol. Wt.:</u>	<u>Formula:</u>
148.27	K ₃ P

Flammability:

Spontaneously flammable (240).

POTASSIUM-ANTIMONY ALLOY

<u>Mol. Wt.:</u>	<u>Formula:</u>
(K ₃ Sb) 239.06	K ₃ Sb
(K ₅ Sb) ₄ 682.54	K ₅ Sb ₄

Thermodynamic properties:

heat of formation (K₃Sb): -17850 ±2000 cal/g atom (at 298°K) (87).

Flammability:

Spontaneously flammable (240).

^{ALUM}
LANTHANUM-ANTIMONY ALLOY

Mol. Wt.:

(La₂Sb) 399.60

(LaSb) 259.68

(LaSb₂) 382.44

Formula:

La₂Sb
LaSb
LaSb₂} (235)

Flammability:

Spontaneously flammable (235).

LITHIUM PHOSPHORUS ALLOY

Mol. Wt.:

37.91

Formula:

LiP

Flammability:

Spontaneously flammable (240).

MANGANESE-BISMUTH ALLOY

Mol. Wt.:

263.93

Formula:

MnBi

Synthesis:

Alloy prepared through melting a stoichiometric mixture of manganese and bismuth becomes pyrophoric after mechanical comminution (240).

Flammability:

Spontaneously flammable (240).

SODIUM AMALGAM

Mol. Wt.:

(Hg₃Na) 624.82

(Hg₈Na₇) 1765.81

(Hg₂Na₅) 516.17

(Hg₄Na) 825.43

(Hg₂Na) 424.21

(HgNa) 223.60

(Hg₂Na₃) 470.19

Formula:

Hg₃Na, Hg₈Na₇, Hg₂Na₅, Hg₂Na₃,
Hg₄Na, Hg₂Na, HgNa, Hg₂Na₅ (85)

Characteristics:

Hg₂Na Solid-hexagonal c-32 ordered structure

HgNa Solid-orthogonal crystal

Hg₂Na₃ Solid tetragonal crystal

Hg₂Na₅ Solid rhombic crystal

Hg₄Na Solid-hexagonal

} (85)

Synthesis:

(1) Clean sodium metal is cubed (5 mm), spear with pointed glass rod and rapidly introduce below

surface of warm (30° - 40°C) pure mercury (80); (2) protect sodium by layer of toluene and melt, then add mercury in drops (80).

Unique conditions, reaction products:

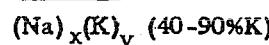
Moisture hazardous solid, decomposes water to yield hydrogen (27).

Flammability:

Liable to produce fire upon becoming moist or in contact with water (27).

SODIUM-POTASSIUM ALLOY

Formula:



Characteristics:

Liquid - silver white to yellow
orange (in air) (142)

Toxicity:

Liquid causes severe skin and eye burns (142).

Unique conditions, reaction products:

Reacts with water, generates sufficient heat to ignite the hydrogen produced in the presence of air (198); reacts violently with CCl_4 and CO_2 (142).

Handling:

Protect from physical damage and keep away from water, avoid high temperature (142).

Thermodynamic properties:

xNa	Gibbs free energy
40%	245 cal/g atom
60%	245 cal/g atom
80%	190 cal/g atom
90%	135 cal/g atom

} (86)

Military and industrial uses:

Used as efficient heat transfer medium in some nuclear power developments, certain engines and unipolar generators, in unipolar machines serves as current collector for high rotor currents (198).

Flammability:

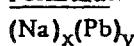
Spontaneously flammable in air above 115°C (139).

SODIUM LEAD ALLOY

Mol. Wt.:

($\text{Na}_{15}\text{Pb}_4$)	1173.69
(Na_5Pb_2)	529.37
(Na_9Pb_4)	1035.75
(NaPb)	230.20

Formula:



} (88)

Thermodynamic properties:

<u>xPb</u>	<u>Gibbs free energy</u>	<u>Enthalpy</u>	<u>Entropy</u>	{ (88)
.2 ($\text{Na}_{15}\text{Pb}_4$)	-3800 cal/g atom	-400 cal/g atom	-.7 cal/ $^{\circ}\text{Kg}$ atom	
.286 (Na_5Pb_2)	-4900 cal/g atom	-5000 cal/g atom	-.4 cal/ $^{\circ}\text{Kg}$ atom	
.308 (Na_9Pb_4)	-5000 cal/g atom	-5200 cal/g atom	-.7 cal/ $^{\circ}\text{Kg}$ atom	
.50 (NaPb)	-5350 cal/g atom	-5800 cal/g atom	-1.5 cal/ $^{\circ}\text{Kg}$ atom	
.70 (β)	-3450 cal/g atom (± 400)	-3300 cal/g atom (± 500)	-.6 cal/ $^{\circ}\text{Kg}$ atom (± 1.0)	

Flammability:

When wet yields H_2 which may ignite spontaneously (27).

NICKEL-IRON ALLOY

Formula:

$(\text{Ni})_x(\text{Fe})_y$
Unites in all proportions (131)

Synthesis:

Combine iron and nickel oxalate in nitrogen, reduce with hydrogen at 150°C to yield iron-nickel alloy (240).

Flammability:

Spontaneously flammable alloy (240).

NICKEL LANTHMIUM

Mol. Wt.:

256.34

Formula:

Ni_2La (239)

Flammability:

Spontaneously flammable (238)

RUBIDIUM-ARSENIC ALLOY

Mol. Wt.:

331.36

Formulas:

Rb_3As (240)

Flammability:

Spontaneously flammable (240)

RUBIDIUM-BISMUTH ALLOY

Formulas:

Rb_3Bi (240)

Flammability:

Spontaneously flammable (240).

RUBIDIUM-ANTIMONY ALLOY

Mol. Wt.:
 (Rb_3Sb) 378.20
 (Rb_5Sb_4) 487.04

Formula:
 Rb_3Sb (240)
 Rb_5Sb_4

Flammability:

Spontaneously flammable (240).

THORIUM SILVER ALLOY

Unique conditions, reaction products:
 $(Th)_x(Ag)_y + \text{air} \rightarrow ThO_2 + Ag$

Formula:
 $(Th)_x(Ag)_y$

Flammability:

The self-ignition of silver-thorium alloys is based on the spontaneous oxidation of thorium following the decomposition of H_2O . The hydrogen evolved by the decomposition of H_2O burns catalytically under the influence of silver, the energy thereby governing the spontaneous oxidation of thorium (183).

URANIUM-BISMUTH ALLOY

Mol. Wt.:
 (UBi) 447.06
 (U_3Bi_4) 1342.17
 (UBi_2) 656.05

Formula:
 UBi
 U_3Bi_4
 UBi_2 } (240)

Flammability:

Spontaneously flammable (over 30% U very pyrophoric) (240).

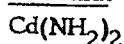
(c) AMIDES, IMIDES

CADMIUM AMIDE

Mol. Wt.:

144.45

Formula:



M. P.:

d. 120°C (79)

d./sp. gr.:

3.05²⁵ (79)

Synthesis:



Flammability:

Spontaneous heating and possible explosion with H₂O (143).

CESIUM AMIDE

Mol. Wt.:

148.93

Formula:



M. P.:

262 ± 1°C (79)

Characteristics:

Solid - white needles (79)

d./sp. gr.:

3.44²⁵₄ (79)

Synthesis:

By action of ammonia on cesium hydride, allow cesium ammonium to stand for some time (131).

Solubility:

d. cold H₂O; s. liquid NH₃ (79)

Thermodynamic properties:

standard heat of formations -25.4 kcal/mol (79)

Flammability:

Incandescent in air (143).

LITHIUM AMIDE

Mol. Wt.:

22.96

Formula:



M. P.:
380°-400°C (132)

Characteristics:
Solid - colorless cubic
needles (79)

d./sp. gr.:
1.178^{17.5} (132)

Synthesis:
 $\text{Li} + \text{NH}_3 \rightarrow \text{LiNH}_2 + 1/2\text{H}_2$ (132)

Unique conditions, reaction products:
Sublimes in NH₃ current (132); LiNH₂ + H₂O → LiOH + NH₃ (132).

Solubility:
s. cold H₂O; d. hot H₂O; sl. s. liquid NH₃, alcohol; i. ether, C₆H₆ (79)

Thermodynamic properties:
heat of formation: 42 kcal/g mol (at 18°C and 760 mm) (132)

Flammability:
Reacts with moisture yielding a dangerous amount of heat (27)

LITHIUM DIMETHYLAMIDE

Mol. Wt.:
50.96

Formula:
LiN(CH₃)₂

Characteristics:
Solid - white (53)

Flammability:
Spontaneously flammable (53)

MAGNESIUM DIAMIDE

Mol. Wt.:
56.36

Formula:
Mg(NH₂)₂

M. P.:
d. 350°-400°C (79)

B.P.:
decomposes (79)

Characteristics:
Solid - gray powder (79)

Synthesis:

(1) from action of ammonia on ether solution of Mg(C₂H₅)₂ or (2) on Mg activated with I₂ at 400°C (132).

Unique conditions, reaction products:

Violent reaction with water to yield ammonia gas (195).

Solubility:

d. cold H₂O alcohol; v. sl. s. liquid NH₃ (79).

Flammability:

Spontaneously flammable in air (195).

SODIUM AMIDE

Mol. Wt.:

39.01

Formula:

Na(NH₂)

Synonyms:

Sodamide

M. P.:

210°C (79)

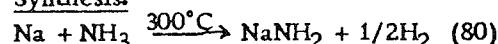
Characteristics:

Solid - white (79)

B.P.:

400°C (79)

Synthesis:



Unique conditions, reaction products:

If heated to decomposition it yields highly toxic fumes of ammonia and sodium oxide, reacts with water or steam to yield heat and toxic corrosive fumes (195).

Solubility:

d. hot and cold H₂O, hot alcohol; . 1 liquid NH₃ (79).

Handling:

Store in sealed containers which prevent contact with air because sodium amide is hydrolyzed by atmospheric moisture; gradual oxidation produces mixtures that detonate on heating (132).

Thermodynamic properties:

heat of solution: -31.06 (at 21°C) (132)

standard heat of formation: -28.4 kcal/mol (79)

Military and industrial uses:

As a dehydrating agent, in the production of indigo and hydrazine, and as an intermediate in the preparation of sodium cyanide (132).

Flammability:

Flames with small amount of water (50).

LEAD IMIDE

Mol. Wt.:

222.21

Formula:

PbNH

Characteristics:

Solid - orange red (131)

Synthesis:

Treat liquid ammonia solution of potassium amide with a solution of lead iodide, and an orange red precipitate of PbNH is slowly formed (131).

Unique conditions, reaction products:

Explodes with heat or dilute acid (131).

Solubility:

d. dilute CH_3COOH , dilute potash lye; slow d. steam (131).

Flammability:

Explodes with H_2O (143).

(d) CARBIDES

BARIUM CARBIDE

Mol. Wt.:
161.36

Formula:
 BaC_2

d./sp. gr.:
3.75 (79)

Characteristics:
Solid - gray crystal (79)

Synthesis:

Fusion of barium carbonate, powdered magnesium and retort carbon results in an intense reaction yielding barium carbide. $[\text{BaCO}_3 + 3\text{Mg} + \text{C} \rightarrow 3\text{MgO} + \text{BaC}_2]$ (131).

Unique conditions, reaction products:

Evolves acetylene vapor in contact with moisture (195).

Solubility:

d. cold H_2O to yield C_2H_2 ; d. acid (195).

Flammability:

Bursts into flames on contact with small amounts of H_2O (50).

CALCIUM CARBIDE

Mol. Wt.:
64.10

Formula:
 CaC_2

d./sp. gr.:
2.22 (103)

Characteristics:
Solid - white tetragonal (103)

B.P.:
2300°C (195)

n_D :
 > 1.175 (79)

Toxicity:

Dust is an eye and respiratory irritant, can cause skin burns (142).

Synthesis:

- (1) heat lime and carbon in an electric furnace (132)
 - (2) $\text{CaO} + 3\text{C} \rightarrow \text{CaC}_2 + \text{CO}$
 - (3) $\text{CaCN}_2 \rightarrow \text{CaC}_2 + 2\text{N}_2 + \text{Ca}$
 - (4) $\text{CaCN}_2 + \text{C} \rightarrow \text{CaC}_2 + \text{N}_2$
- } (80)

Unique conditions, reaction products:

Yields acetylene and hydrated lime on contact with moisture (132).

Solubility:

d. hot and cold H_2O (103).

Handling:

Protect against physical damage, store in noncombustible, well ventilated area (without sprinkler protection) exclude other possible sources of ignition (142).

Military and industrial uses:

Used to produce acetylene for lighting purposes, as a reducing agent, in signal fires for marine service, and to weld and cut metals (132).

Flammability:

Produces sufficient heat to ignite acetylene formed on contact with water or moisture (142).

POTASSIUM GRAPHITE

Mol. Wt.:

KC₈ 135.1

KC₂₄ 327.1

Formula:

KC₈

KC₂₄

Characteristics:

KC₈ Solid-dark copper red to bronze

KC₂₄ Solid-steel blue (79)

Unique conditions, reaction products:

Sensitive to air, moisture and alcohol (195).

Flammability:

Spontaneously flammable in air (80).

POTASSIUM CARBIDE

Mol. Wt.:

64.13

Formula:

KHC₂

d./sp. gr.:

1.37 (79)

Characteristics:

Solid - colorless rhombic

crystals (79)

Unique conditions, reaction products:

Explosive reaction with H₂O (143).

SODIUM CARBIDE

Mol. Wt.:

70.00

Formula:

Na₂C₂

M. P.:

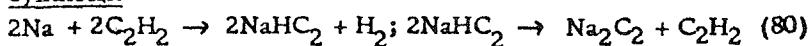
About 700°C (79)

Characteristics:

Solid - white powder (79)

d. / sp. gr. :
1.57515 (79)

Synthesis:



Unique conditions, reaction products:

Reacts with H_2O producing H_2 so violently that an explosion can occur (232).

Solubility:

d. cold H_2O , hot H_2O , alcohol; s. acid (79)

TITANIUM CARBIDE

Mol. Wt. :
59.91

Formula:
 TiC

M. P. :
3140° ± 90°C (79)

Characteristics:
Solid - gray cubic metal (79)

d. / sp. gr. :
4.93 (79)

B. P. :
4820°C (79)

Synthesis:

Heat titanic oxide (160 parts) and carbon (70 parts) in an electric arc furnace for 10 minutes [$\text{TiO}_2 + 2\text{C} \rightarrow \text{TiC} + \text{CO}_2$] (131).

Solubility:

i. cold and hot H_2O ; s. aqua regia, HNO_3 (79)

Military and industrial uses:

Additive with tungsten carbide in making cutting tools and other tools (parts) subjected to thermal shock, arc-melting electrodes; cermets (190).

Flammability:

"As micron-sized titanium carbide was being removed from a ball mill, a cloud of the dust ignited." (143).

URANIUM MONOCARBIDE

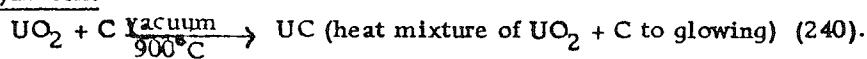
Mol. Wt. :
250.07

Formula:
 UC

M. P. :
2.315 ± 65°C (193)

d. / sp. gr. :
12.97 (193)

Synthesis:



Unique conditions, reaction products:

Reactive with water (193).

Thermodynamic properties:

Thermal conductivity: .06 cal/sec/cm/ $^\circ\text{C}$ (at 100° to 700°C and 5 weight % C) (193)

Military and industrial uses:

Used as fissionable dust carried in a gas in an ADFR (Armour dust fissionable reactor), gas was helium, graphite was used as a moderator and the ducts and chambers were lined with silicon carbide (112).

Flammability:

Less than 40 μ very pyrophoric (240).

URANIUM CARBIDE

Mol. Wt.:

262.05

Formula:

UC₂

M. P.:

2350°-2400°C (79)

Characteristics:

Solid - metallic crystal (79)

d./sp. gr.:

11.28¹⁶ (79)

B. P.:

4370⁷⁶⁰ (79)

Solubility:

d. cold and hot H₂O, dilute inorganic acids; i. alcohol (79)

Flammability:

Spontaneously flammable if particle size less than 40 μ (240).

thermal

ZIRCONIUM CARBIDE

Mol. Wt.:

103.23

Formula:

ZrC

M. P.:

3540°C (190)

Characteristics:

Solid - gray cubic metal (79)

d./sp. gr.:

6.78 (190)

B. P.:

5100°C (190)

Hardness:

.84 mohrs (190)

Synthesis:

Heat zirconium oxide and coke in an electric furnace (190).

Solubility:

i. H₂O, HCl; s. oxidizing acids (190).

Military and industrial uses:

Incandescent filament, abrasive, high temperature electrical conductor (190).

Flammability:

Fine powder spontaneously flammable (190)

ZIRCON CARBIDE OR ZIRCON CARBONITRIDE

Synthesis:

Heat Zircon mineral and carbon in an electric arc furnace to yield Zircon carbide or carbonitride (44)

Flammability:

"Air must be kept away from compound as it cools, or it may go up in a spontaneous display
..." (44).

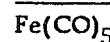
(e) CARBONYLS

IRON PENTACARBONYL

Mol. Wt.:

195.90

Formula:



M. P.:

-21°C (79)

Characteristics:

Liquid - viscous yellow (79)

d./sp. gr.:

1.457²¹ (79)

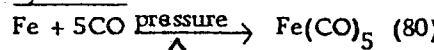
B. P.:

102.8⁷⁴⁹ (79)

Toxicity:

Causes dizziness, nausea, and vomiting on inhalation, followed by unconsciousness, can injure liver, kidneys and brain (195).

Synthesis:



Ignition temperature:

flash point: 5°F (195)

Solubility:

i. cold H₂O; s. alcohol, ether, C₆H₆, alkaline solvents, concentrated H₂SO₄ (79)

Thermodynamic properties:

dipole moment: .64-.81

heat of formation (at 18°C): -189.8 kcal/mol

heat of fusion: 3.25 kcal/mol.

heat of vaporization: 9.0 kcal/mol

} (132)

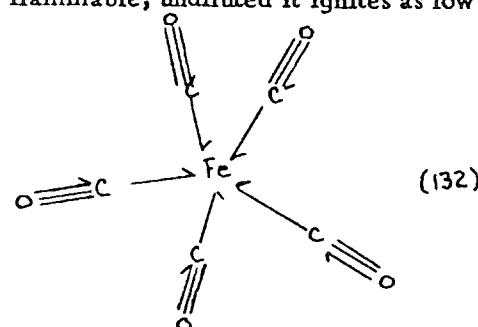
Military and industrial uses:

Used to make carbonyl iron, formerly as antiknock agent in motor fuels (132).

Flammability:

Spontaneously flammable; undiluted it ignites as low as 44°C (99)

Structure:

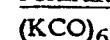


POTASSIUM CARBONYL

Mol. Wt.:

402.68

Formula:



M. P.:
Explodes (79)

Characteristics:
Gray-red (79)

B.P.:
d. 250°C (103)

Toxicity:
Highly toxic (195)

Solubility:
Explodes with cold H₂O, d. alcohol (79).

Synthesis:
Pass dry purified CO into a solution of potassium in liquified ammonia at -50°C, blue color gradually becomes weaker and changes to pink, allow ammonia to evaporate, yields K(CO)₆ (131).

Flammability:
Detonates with air, H₂O or heat (100°C) (131).

SODIUM CARBONYL

Mol. Wt.:
79

Formula:
Na(CO)₂

Characteristics:
Solid - white powder,
black-tint (131)

Toxicity:
Highly toxic (195).

Unique conditions, reaction products:
Explodes with air or H₂O (143).

Synthesis:
Pass pure dry CO into solution of sodammonium in liquified ammonia at about -50°C, blue color becomes lilac tinted, evaporate ammonia, leaving Na(CO)₂ (131).

NICKEL CARBONYL

Mol. Wt.:
170.75

Formula:
Ni(CO)₄

M. P.:
-25°C (79)

Characteristics:
Liquid - colorless volatile or
solid - needles (79)

d./sp. gr.:
1.32¹⁷ (79)

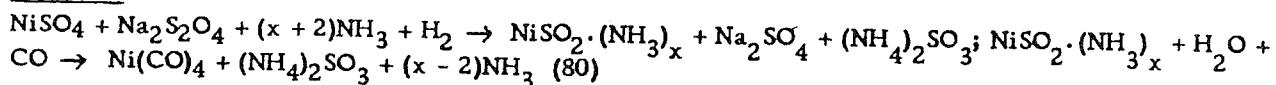
B.P.:
43°C (79)

V.P.:
400 25.8 (79)

Toxicity:

High on inhalation (local and systemic); slight allergen; high on inhalation (chronic systemic); Tolerance level ACGIH .001 ppm (.007 mg/m³) (195).

Synthesis:



Solubility:

s. aqua regia, alcohol, ether, C₆H₆, HNO₃; i. dilute acid, dilute alkaline solvent (79).

Flammability:

In the presence of air, Ni(CO)₄ forms a deposit which becomes peroxidized, this tends to decompose and ignite (143).

131

DIVANADIUM DODECACARBONYL

Mol. Wt.:

438.02

Formula:

V₂(CO)₁₂

Characteristics:

Dark blue solution, gives yellow to orange solution in toluene (175)

Synthesis:

Isolated from reaction of ditoluene vanadium and carbon monoxide (175).

Unique conditions, reaction products:

Volatile, readily sublimes at room temperature and atmospheric pressure (175).

Solubility:

s. ether, hydrocarbons; d. CS₂ (175).

Flammability:

Spontaneously flammable (175).

(f) HALIDES

ARSENIC TRICHLORIDE

Mol. Wt.:

181.28

Formula:

AsCl₃

M. P.:

-8.5°C (79)

Characteristics:

Liquid - oily (190)

d./sp. gr.:

2.163²⁰ (79)

B. P.:

63⁷⁵² (79)

n¹⁴F

D₃

1.621 (79)

Synthesis:

(1) from action of chlorine on arsenic; (2) distil arsenic trioxide with concentrated HCl (190).

Unique conditions, reaction products:

Fumes in moist air (190).

Solubility:

s. HCl, HBr, PCl₃, alcohol, ether; d. hot and cold H₂O (79).

Thermodynamic properties:

	<u>Gas</u>	<u>Liquid</u>	
standard heat of formation:	-71.5 kcal/mol	-80.2 kcal/mol	
standard free energy of formation:	-68.5 kcal/mol	-70.5 kcal/mol	
entropy (at 25°C):	78.2 e.u.	55.5 e.u.	}

(79)

Military and industrial uses:

Used in poison gas and ceramics (190).

BORON ARSENOTRIBROMIDE

Mol. Wt.:

328.47

Formula:

BBr₃AsH₃

Flammability:

With air or oxygen it is readily oxidized and in most cases ignites spontaneously (143).

BORON TRIBROMIDE

Mol. Wt.:

250.54

Formula:

B(Br)₃

M. P.:

-46°C (79)

Characteristics:

Liquid - colorless fuming

d./sp. gr.:
2.6431₄^{18.4} (79)

B.P.:
91.3 ± 25°C (79)

n_D:
16.3 (79)

Synthesis:

- (1) $\text{AlBr}_3 + \text{BF}_3 \rightarrow \text{BBr}_3 + \text{AlF}_3$ (80)
(2) $\text{B} + 1/2\text{Br}_2 \rightarrow \text{BBr}_3$

Unique conditions, reaction products:

Explodes with H_2O (143).

Solubility:

d. cold H_2O ; s. alcohol, CCl_4 (79)

Thermodynamic properties:

	<u>Solid</u>	<u>Liquid</u>	<u>(79)</u>
standard heat of formation:	-44.6 kcal/mol	-52.8 kcal/mol	
standard free energy of formation:	-51.0 kcal/mol	-52.4 kcal/mol	
entropy (at 25°C):	77.49 e.u.	54.7 e.u.	

TETRACHLORODIBORANE

Mol. Wt.:
163.47

Formula:
 B_2Cl_4

M. P.:
-91°C (226)

Characteristics:
Liquid colorless (226)

B.P.:
65.5°C (226)

Solubility:
d. H_2O (226)

Synthesis:

Made by passing BCl_3 through a discharge between mercury electrodes (230).

Thermodynamic properties:

heat of fusion:	2579 ± 4 cal/mol	<u>(155)</u>
heat of vaporization (at 220°K):	8670 ± 70 cal/mol	
entropy (at 1 atmosphere and 220°K):	80.27 e.u.	

Flammability:

Spontaneously flammable (226); May be due to presence of $(\text{BCl})_4$ even though carefully purified (230).

MONOCHLORODIBORANE

Mol. Wt.:
62.14

Formula:
 $\text{H}_3\text{BBH}_2\text{Cl}$

M. P.:
-142°C (226)

Characteristics:
Gas - colorless (226)

B.P.:
0°C (226)

Solubility:

s. organic solvents; d. H₂O, air (226).

Flammability:

Spontaneously flammable (226).

BORON CHLORIDE TETRAMER

Mol. Wt.:

185.12

Formula:

(BCl)₄

M. P.:

d. 75°C (226)

Characteristics:

Solid - yellow crystals (226)

V.P.:

231.5

6834

(226)

Flammability:

Spontaneously flammable (226).

BISMUTH PENTAFLUORIDE

Mol. Wt.:

304.00

Formula:

BiF₅

M. P.:

Sublimes at 550°C (195)

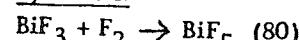
Characteristics:

Solid - white crystal (195)

Toxicity:

Highly toxic and irritating to mucous membranes, skin, eyes, and respiratory tract (195).

Synthesis:



Unique conditions, reaction products:

Reacts violently with water and petrolatum (195).

Flammability:

Reacts with H₂O sometimes with ignition (80).

BROMINE PENTAFLUORIDE

Mol. Wt.:

174.90

Formula:

BrF₅

M. P.:

-61.3°C (79)

Characteristics:

Liquid - colorless (79)

V.P.:

7 psia (at 70°F) (190)

d./sp. gr.:

2.57⁰ (79)

B.P.:

40.5°C (79)

V.d.:

6.05 (195)

Toxicity:

High (acute, local) as irritant, on ingestion and on inhalation; high (chronic, local) as irritant, on ingestion and on inhalation (195).

Synthesis:

Nearly explosive reaction with H₂O; fumes strongly in air (80).

Solubility:

d. hot and cold H₂O (79)

Military and industrial uses:

Oxidizer in liquid rocket propellants (190).

CALCIUM HYPOCHLORITE

(With > 39% available chlorine)

Mol. Wt.:

91.53

Formula:

CaOCl

Unique conditions, reaction products:

Decomposes in H₂O; with heat or sun may decompose, spontaneously rupturing container, vapors evolved may ignite spontaneously in air (54).

CHLORINE TRIFLUORIDE

Mol. Wt.:

92.45

Formula:

ClF₃

M. P.:

-83°C (79)

F.P. -105°C (150)

Characteristics:

Gas - colorless, sweet odor (79)

V. d.:

3.14 (79)

d./sp. gr.:

1.7713 (79)

B.P.:

11.3°C (79)

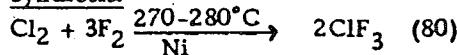
Viscosity (liq.): (1)

.438 cp (at 67°F)

Toxicity:

Emits highly toxic fumes with H₂O, -COOH, or acid fumes (195); strongly attacks bronchi (80); MAC (Maximum acceptable concentration) .1 ppm (1).

Synthesis:



Unique conditions, reaction products:

Ignites on contact with many organic compounds, reacts violently with oxidizable materials (195); reacts violently with H₂O (62).

Solubility:

d. cold and hot H₂O (79)

Handling:

Keep free from excessive heat and moisture in stainless steel tanks or calcium alloys, position tanks so that they cannot be easily tipped over or rolled (30).

Thermodynamic properties:

heat of fusion (at freezing point): 35.45 Btu/lb
 heat of vaporization (at freezing point): 128.3 Btu/lb
 heat capacity (at 68°F) (gas): .169 Btu/lb
 heat capacity (liq): .304 Btu/lb
 critical temperature: 345.2°F
 critical pressure: 837.7 psia

{(1)}

Military and industrial uses:

Used as incendiary material by the military in World War II, used more recently as a fluorinating agent and as an oxidizer in rocket engines (62).

Flammability:

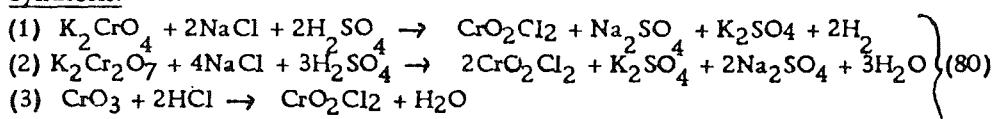
Spontaneously flammable gas (195).

CHROMYL CHLORIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
154.90	CrO ₂ Cl ₂	Chromium oxychloride
<u>M. P.:</u>	<u>Characteristics:</u>	<u>V.P.:</u>
-96.5°C (79)	Liquid -dark red (79)	2020 (195)

<u>d. /sp. gr.:</u>	<u>B.P.:</u>
1.911 (79)	117°C (79)

Synthesis:



Unique conditions, reaction products:

Forms a smoke with atmospheric moisture (80).

Solubility:

d. hot and cold H₂O, alcohol; s. ether, CH₃COOH (79)

Thermodynamic properties:

standard heat of formation (at 25°C) (liq): -135.7 kcal/mol (79)

LITHIUM HYPOCHLORITE (With > 39% available chlorine)

<u>Mol. Wt.:</u>	<u>Formula:</u>
58.39	LiOCl

Characteristics:

Solid - white powder (54)

Unique conditions, reaction products:

Decomposes in H₂O; with heat or sun may decompose spontaneously rupturing containers, the vapors evolved may ignite spontaneously in air (54).

SODIUM HYPOCHLORITE

Mol. Wt.:
74.45

Formula:
NaOCl

M. P.:
d. (195)

B. P.:
d. (195)

Synthesis:



Unique conditions, reaction products:

Decomposes explosively in air due to CO₂ (80).

Thermodynamic properties:

standard heat of formation: -82.7 kcal/mol (79).

PHOSPHORUS TRICHLORIDE

Mol. Wt.:
137.33

Formula:
PCl₃

M. P.:
-112°C (79)

Characteristics:
Liquid - colorless fuming (79)

V. P.:
10021 (195)

d./sp. gr.:
5.4 (79)

B. P.:
75.5749 (79)

V. d.:
4.75 (195)

$$\frac{n_{D_2}^{14}}{1.516} \quad (79)$$

Toxicity:

Vapors irritating, can cause severe burns (190); threshold limit .5 ppm (195).

Synthesis:

Pass stream of chlorine gas over melted phosphorus, heated red phosphorus, or through carbon disulfide solution of yellow phosphorus, obtain liquid trichloride by fractional distillation (214).

Solubility:

d. hot and cold H₂O; s. ether, C₆H₆, chloroform, CS₂, CCl₄ (79).

Handling:

Keep cool, away from water, steam, acids, and oxidizing materials (195).

Thermodynamic properties:

standard heat of formation: -73.22 kcal/mol
 free energy of formation (at 25°C): -68.42 kcal/mol
 standard entropy: 74.49 e.u.

} (79)

Military and industrial uses:

PCl_3 is used as a chlorinating agent in the manufacture of synthetic organic chemicals, specifically to replace hydroxyl groups by chlorine (214).

Flammability:

Contact with H_2O may cause fire (190).

PHOSPHORUS PENTACHLORIDEMol. Wt.:

208.24

Formula:

PCl_5

Synonyms:

Phosphorus perchloride
Phosphorus chloride

M. P.:

c. 166.8°C (79)

Characteristics:

Solid yellow white
tetragonal (79)

V.P.:
 155.5 (195)

d./sp. gr.:

465^{296} (79)

B.P.:

sublimes 162°C (79)

Synthesis:

Pass stream of chlorine gas over melted phosphorus, heated red phosphorus, or through a CS_2 solution of yellow phosphorus (excess treatment with chlorine) (214).

Unique conditions, reaction products:

Moisture hazardous, decomposes with H_2O to yield heat (27).

Solubility:

d. cold H_2O ; s. CS_2 or CCl_4 (79)

Thermodynamic properties:

standard heat of formation: $-95.35 \frac{\text{gas}}{\text{kcal/mol}}$
 free energy of formation (at 25°C): -77.59 kcal/mol
 standard entropy: 84.3 e.u.

} (79)

Military and industrial uses:

Catalyst in manufacture of acetyl cellulose, for replacing hydroxyl-groups by chlorine, particularly converting acids into acid chlorides (214).

PHOSPHORUS OXYCHLORIDEMol. Wt.:

153.33

Formula:

POCl_3

<u>M. P.:</u> 2°C (79)	<u>Characteristics:</u> Liquid - colorless, fuming (79)
<u>d. / sp. gr.:</u> 1.675 (79)	<u>B. P.:</u> 105.3°C (79)
	<u>n_D:</u> 1.46025.1 (79)

Unique conditions, reaction products:
Hydrolyzes violently with H₂O (217).

Solubility:
d. cold and hot H₂O, alcohol, acids (79)

Thermodynamic properties:

standard heat of formation:	<u>gas</u> -141.5 kcal/mol	<u>liquid</u>
free energy of formation (at 25°C):	-130.3 kcal/mol	{ (79)
standard entropy:	77.59 e.u.	
heat of vaporization:		8.06 kcal/mol
critical temperature:		329°C
troutons constant:		21.3 cal/°K
surface tension (at 25°C):		31.6 dynes/cm } (132)

TRIFLUORO PHOSPHANE SULFIDE = THIOPHOSPHORYL FLUORIDE

<u>Mol. Wt.:</u> 120.04	<u>Formula:</u> (S)PF ₃
<u>M. P.:</u> -148.8°C (226)	<u>Characteristics:</u> Gas (226)
	<u>B. P.:</u> d. -52.3°C (226)

Solubility:
d. H₂O; s. ether; i. organic solvents (226)

Flammability:
Spontaneously flammable (226).

SULFURYL CHLORIDE

<u>Mol. Wt.:</u> 134.97	<u>Formula:</u> SO ₂ Cl ₂
<u>M. P.:</u> -54.1°C (79)	<u>Characteristics:</u> Liquid - colorless (79)
<u>d. / sp. gr.:</u> 1.66720 4 (79)	<u>B. P.:</u> 69.1°C (79)
	<u>n_D:</u> 1.444 (79)

Unique conditions, reaction products:

With moisture in air yields smoke; decomposes with moisture forming H_2SO_4 and HCl (171).

Solubility:

d. hot and cold H_2O ; s. C_6H_6 , CH_3COOH (79)

Thermodynamic properties:

standard heat of formation (liq): -49.2 kcal/mol (79)

Military and industrial uses:

Smoke producer in World War II; also used with certain toxic gases to render them visible (171).

TETRABROMOSILANE

Mol. Wt.:

347.72

Formula:

$SiBr_4$

M. P.:

5.4°C (79)

Characteristics:

Solid - cubic
Liquid - fuming (79)

d./sp. gr.:

(liq) 2.7715²⁵₄ (79)

(sol) 3.292 -79 (79)

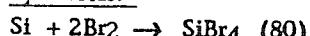
B. P.:

154°C (79)

V. d.:

2.82 (195)

Synthesis:



Unique conditions, reaction products:

Reacts with H_2O to yield heat and fumes (195).

Solubility:

d. hot and cold H_2O , H_2SO_4 (79)

Thermodynamic properties:

standard heat of formation (liq): -95.1 kcal/mol (79)

SILICON CHLORIDE

Mol. Wt.:

169.90

Formula:

$SiCl_4$

M. P.:

-70°C (79)

Characteristics:

Liquid - colorless fuming (79)

d./sp. gr.:

(liq) 1.48320 (79)

(sol) 1.90-97 (79)

(gas)>.59 (79)

B. P.:

57.57°C (79)

Toxicity:

High (acute local) as irritant, on ingestion, and on inhalation (195).

Synthesis:



Unique conditions, reaction products:

Fumes heavily upon exposure to air (80).

Solubility:

d. hot and cold H_2O , alcohol (79)

(171)

Thermodynamic properties:

	<u>gas</u>	<u>liquid</u>	
standard heat of formation:	-145.7 kcal/mol	-153.0 kcal/mol	
standard free energy of formation:	-136.2 kcal/mol	-136.9 kcal/mol	
standard entropy:	79.2 e.u.	37.2 e.u.	}

(79)

Military and industrial uses:

Used as smoke screens in warfare and in the preparation of pure silicon (132).

TRIBROMOSILANE

Mol. Wt.:

268.9

Formula:

SiHBr_3

Synonyms:

Silicobromoform

M. P.:

-73.5°C (195)

Characteristics:

Liquid - mobile,
inflammable (195)

Dipole moment:

.79 (132)

d./sp. gr.:

$2.7\frac{1}{4}$ (195)

B.P.:

112°C (195)

V.P.:

8.8^0 (195)

Toxicity:

Readily hydrolyzes to liberate HBr, a powerful irritant (195).

Synthesis:



Solubility:

d. hot and cold H_2O , NH_3 (79)

Flammability:

Spontaneously flammable in air (195).

TRICHLOROSILANE

Mol. Wt.:

135.45

Formula:

SiHCl_3

Synonyms:

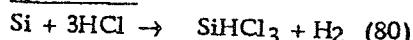
Silicochloroform

<u>M. P.:</u>	<u>Characteristics</u>	
-126.5°C (79)	Liquid - colorless (79)	
-134°C (195)		
<u>d./sp. gr.:</u>	<u>B. P.:</u>	<u>Dipole moment:</u>
1.34 (79)	33758 (79)	.97 (132)
	<u>n_D²⁰:</u>	<u>Viscosity:</u>
	1.4020 (132)	.397 cp (at 0°C) (132)
	<u>n_D²⁵:</u>	<u>V. d.:</u>
	1.3983 (132)	4.7 (195)

Toxicity:

Moderate (acute local) as irritant on inhalation; moderate (acute systemic) on ingestion, inhalation (195).

Synthesis:



Unique conditions, reaction products:

Violent reaction with water (27).

Ignition temperature:

flash point: < 20°F (195)

Solubility:

d. hot and cold H₂O; s. CS₂, CCl₄, chloroform, C₆H₆ (79)

Flammability:

Spontaneously flammable in air (195).

BROMO SILANE

<u>Mol. Wt.:</u>	<u>Formula:</u>
111.02	SiH ₃ Br
<u>M. P.:</u>	<u>Characteristics</u>
-94°C (79)	Gas - colorless (79)
<u>d./sp. gr.:</u>	<u>B. P.:</u>
1.72-80 (79)	1.9°C (79)
1.533 ⁰ (79)	
<u>Flammability:</u>	
Explodes in air (79)	

SILICON HEXACHLORIDE

<u>Mol. Wt.:</u> 268.89	<u>Formula:</u> <chem>Si2Cl6</chem>	<u>Synonyms:</u> Hexachlorodisilane
<u>M. P.:</u> -1°C (79)	<u>Characteristics:</u> Liquid - colorless (79)	<u>V. d.:</u> 9.29 (195)
<u>d./sp. gr.:</u> 1.58 ⁰ (79)	<u>B. P.:</u> 145°68 (79)	<u>n_D¹⁸:</u> 1.4748 (79)

Synthesis:

Pass vapor of silicon tetrachloride over white-hot silicon (contained in a porcelain tube), by cooling the products rapidly Si2Cl6 is separable by fractional distillation (131).

Solubility:

d. hot and cold H₂O, alcohol (79)

Flammability:

Spontaneously flammable liquid; vapors ignite spontaneously in air (27).

DISILYAMINO DICHLOROBORINE

<u>Mol. Wt.:</u> 157.93	<u>Formula:</u> <chem>(SiH3)2NBCl2</chem>	
<u>M. P.:</u> d. 62°C (226)	<u>Characteristics:</u> Solid (226)	<u>V. P.:</u> 25 ²² (226)

Flammability:

Spontaneously flammable (226).

ANTIMONY PENTACHLORIDE

<u>Mol. Wt.:</u> 299.02	<u>Formula:</u> <chem>SbCl5</chem>	
<u>M. P.:</u> 2.8°C (79)	<u>Characteristics:</u> Liquid - white (79) Solid - monoclinic (79)	<u>V. P.:</u> 122.7 (195)
<u>d./sp. gr.:</u> 2.336 ²⁰ ₄ (79)	<u>B. P.:</u> 79 ²² (79)	<u>n_D¹⁴:</u> 1.601 (79)

Synthesis:

Pass chlorine into molten SbCl3 (132).

Unique conditions, reaction products:

Gives white smoke with atmospheric moisture (167).

Solubility:d. hot and cold H₂O; s. HCl, tartaric acid, methyl dichloride (79)Thermodynamic properties:

standard heat of formation:	<u>gas</u> -93.9 kcal/mol	<u>liquid</u> -104.8 kcal/mol	(79)
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TIN TETRACHLORIDEMol. Wt.:
260.50Formula:
SnCl₄M. P.:
-33°C (79)Characteristics:
Liquid - colorless or
solid - cubic (79)d./sp. gr.:
2.28 (79)B.P.:
114°C (79)n_D:
1.512 (79)Synthesis:

Formed by direct chlorination of metallic tin (172).

Unique conditions, reaction products:Produces smoke with moisture [SnCl₄ + 4H₂O → Sn(OH)₄ + 4HCl] (19).Solubility:s. cold H₂O, ether; d. hot H₂O (79)Thermodynamic properties:

standard heat of formation:

Liquid
-179.3 kcal/mol
-161.2 kcal/mol
60.4 e.u.

standard free energy of formation:

 } (79)

standard entropy :

TITANIUM DIBROMIDEMol. Wt.:
207.72Formula:
TiBr₂M. P.:
d. > 500°C (79)Characteristics:
Solid - black powder (79)d./sp. gr.:
4.31 (79)Solubility:s. cold H₂O with evolution of H₂ (79)

Thermodynamic properties:

standard heat of formation: 95 kcal/mol (79)

Flammability:

Spontaneously flammable (240); ignites in moist air (80)

TITANIUM DICHLORIDE

Mol. Wt.:

118.81 (79)

Formula:TiCl₂Synonyms:

Titanium bichloride

M. P.:Sublimes H₂ (79)Characteristics:

Solid - light brownish black, hexagonal, deliquescent (79)

d./sp. gr.:

3.13 (79)

B.P.:

d. 475 (in vacuum) (79)

Synthesis:Solubility:d. cold H₂O; s. alcohol; i. ether, chloroform CS₂ (79)Thermodynamic properties:

standard heat of formation:

crystalline

-114 kcal/mol (79)

Flammability:Ignites in moist air (80); hisses like a red-hot iron in H₂O and dissolves with evolution of H₂ (131).

TITANIUM TRICHLORIDE

(Anhydrous)

Mol. Wt.:

154.26 (79)

Formula:TiCl₃M. P.:

d. 440°C (79)

Characteristics:

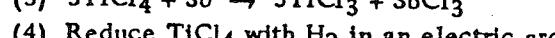
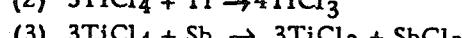
Solid - dark violet deliquescent (79)

d./sp. gr.:

2.64 (79)

B.P.:

660108 (79)

Synthesis:

}

(80)

Solubility:

s. cold H₂O, hot H₂O; v. s. alcohol; s. HCl; i. ether (79)

Thermodynamic properties:

standard heat of formation: crystalline
-165 kcal/mol (79)

Military and industrial uses:

Used as reducing agent; in organic synthesis, as co-catalyst for polyolefin polymerization; in organo-metallic synthesis involving titanium (190).

Flammability:

Spontaneously flammable in air (124).

TITANIUM TETRACHLORIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
189.71	TiCl ₄	Titanic chloride
<u>M. P.:</u> -25°C (79)	<u>Characteristics:</u> Liquid - light yellow (79)	<u>V.P.:</u> 1021.3 (195)
<u>d./sp. gr.:</u> (liq) 1.726 (sol) 2.06 ⁻⁷⁹ (79)	<u>B.P.:</u> 136.4°C (79)	<u>n</u> ^{10.5} <u>D:</u> 1.61 (79)

Toxicity:

High (acute local) as irritant, on inhalation; high (chronic local) on inhalation; can cause severe burns but do not wash with H₂O (severe burns due to formation of HCl) (195).

Synthesis:



Unique conditions, reaction products:

Produces white fumes in moist air; liberates heat and HCl on contact with moisture (195); readily forms adducts with HN₃, pyridine and non metal chlorides (89).

Solubility:

s. cold H₂O; d. hot H₂O; s. dilute HCl, alcohol (79)

Thermodynamic properties:

standard heat of formation: 763.2 ± 2.9 kg/mol (-182.4 ± .7 kcal/mol) (101)

triple point temperature: 249.045 ± .010°K (141)

Military and industrial uses:

Chemical warfare symbol is FM, called by Germans "F-stoff", produces smoke in air, in combination with NH₃ vapor gives a denser smoke (19, 20).

TITANIUM DIODIDE

Mol. Wt.:
301.71

Formula:
 TiI_2

M. P.:
600°C (79)

Characteristics:
Solid - black hygroscopic (79)

d./sp. gr.:
4.99 (79)

B.P.:
1000°C (79)

Synthesis:

Reduce TiI_4 to TiI_2 by silver or mercury. Arrange two porcelain boats in a porcelain tube (the anterior one containing Hg and the posterior one TiI_4), raise the temperature to dull redness while a current of hydrogen is passed through the tube. A sublimate of mercuric iodide and unchanged TiI_4 is formed in the cool receiver and TiI_2 is formed near the exit of the tube (131).

Solubility:

d. cold H_2O , alkaline solvents; s. concentrated HF, concentrated HCl (79)

Thermodynamic properties:

<u>standard heat of formation:</u>	<u>crystalline</u> -61 kcal/mol (79)
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Flammability:

Ignites in moist air (80).

VANADYL CHLORIDE

Mol. Wt.:
173.30

Formula:
 $VOCl_3$

Synonyms:
Vanadium oxytrichloride

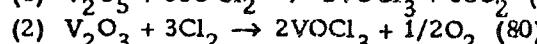
M. P.:
-77 ± 2°C (79)

Characteristics:
Liquid - yellow (79)

d./sp. gr.:
1.82⁹ (79)

B.P.:
126.7°C (79)

Synthesis:



Unique conditions, reaction products:

Forms orange smoke with atmospheric moisture; smoke density is increased by addition of $TiCl_4$; reacts with H_2SO_4 to yield $VOCl_3 \cdot SO_3$ which with moisture yields dense white smoke (167 168).

Solubility:

s. d. cold H_2O ; s. alcohol, ether, acetic acid, Br_2 (79)

Thermodynamic properties

standard heat of formations -172 kcal/mol (79)

crystalline

$$-172 \text{ kcal/mol} \quad (79)$$

ZIRCONIUM DIBROMIDE

Mol. Wt.:

251.95

Formula:

$$\overline{\text{Zr(Br)}_2}$$

Synonyms:

Dibromo zircine

M.P.

d. 350°C (226)

Characteristics

Solid - black powder (226)

Toxicity:

Dangerous upon decomposition, toxic fumes of bromide are emitted (195).

Unique conditions—reaction products

Vigorous reaction with oxidizing materials (195)

Solubility:

d. cold H₂O (226)

Thermodynamic properties

crystalline

standard heat of formation:

Δ_rH° = -120 kcal/mol (79)

Flammability:

Spontaneously flammable (226)

(g) HYDRIDES

ALUMINUM BOROHYDRIDE

Mol. Wt.:

71.54

Formula:

Al(BH₄)₃

Synonyms:

Aluminum tris
(tetrahydroborane)

M. P.:

71.54

Characteristics:

Liquid - colorless (226)

V. P.:

Log P = 7.808 - 1565/T;
1200, 25717 (226)

d./sp. gr.:

.5610, .53310, .544²⁰,
.53729.4 (226)

B. P.:

44.5°C (226)

Synthesis:

- (1) (CH₃)₃Al + 2B₂H₆ → (CH₃)₃B + Al(BH₄)₃ (70)
- (2) 2AlH₃ + 3B₂H₆ → 2Al(BH₄)₃ (70)
- (3) LiAlH₄ + 2B₂H₆ → LiBH₄ + Al(BH₄)₃ (70)

Unique conditions, reaction products:

Forms addition compounds readily with amines (226).

Solubility:

d. H₂O (explodes); s. organic solvent (226).

Thermodynamic properties:

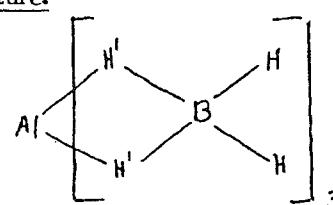
heat of vaporization: 7160 cal/mol (226)

heat of combustion: 13760 cal/g (226)

Flammability:

Vapor detonates spontaneously and violently on contact with air containing moisture (196).

Structure:



Al - B = 2.15 Å
Al - H' = 2.1 Å
B - H' = 1.28 Å
B - H = 1.21 Å

} (174)

ALUMINUM HYDRIDE

Mol. Wt.:

120.0

Formula:

(AlH₃)_x

M. P.:

d. 100°C (226)

Characteristics:

Solid - gray white (226)

Synthesis:

- (1) $3\text{LiAlH}_4 + \text{AlCl}_3 \rightarrow 4(\text{AlH}_3) + 3\text{LiCl}$ (117)
(2) $3\text{LiH} + \text{AlCl}_3 \xrightarrow{\text{ether}} \text{AlH}_3 + 3\text{LiCl}$ (117)

Solubility:

d. H_2O , alcohol, air; s. ether (226)

Thermodynamic properties:

heat of formation (at 298°K) (gas): 18 ± 10 kcal/mol
entropy (at 298°K): 47.7 e.u.
free energy of formation (at 298°K): 20.9 kcal/mol

} (119)

Flammability:

Spontaneously flammable in air or O_2 (118).

TRISILYL ARSINE

Mol. Wt.:

168.25

Formula:

$\text{As}(\text{SiH}_3)_3$

B.P.:

d. 25°C (226)

Characteristics:

Liquid (226)

V.P.:

1.7^0 (226)

Solubility:

d. H_2O (226)

Flammability:

Spontaneously flammable (226).

TRIBROMO BORINE ARSINE

Mol. Wt.:

323.54

Formula:

BBr_3AsH_3

M.P.:

7°C (226)

Characteristics:

Liquid (226)

B.P.:

d. 40°C (226)

Flammability:

Spontaneously flammable (226).

DIBROMO BORINE PHOSPHINE

Mol. Wt.:

284.59

Formula:

BBr_3PH_3

Characteristics:

Solid - white amorphous (226)

Flammability:

Spontaneously flammable (226).

DIBORANE

Mol. Wt.:

26.67

Formulas:

B₂H₆

Synonyms:

Boron hydride

Boroethane

M. P.:

-165.5°C (226)

Characteristics:

Gas - colorless

V.P.:

224-112 (195)

d./sp. gr.:

(liq) .447-112 (195)

(sol) .577-183 (195)

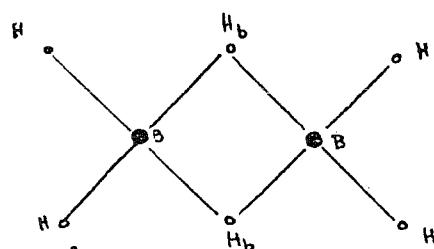
B.P.:

-92.5 (226)

V.d.:

.96 (142)

Structure:



B - H = 1.87 ± .010 Å

B - H_b = 1.334 ± .027 Å

B - B = 1.77 ± .013 Å (124)

H is the terminal H atom

H_b is the bridge H atom

Toxicity:

High as irritant; is a lung irritant and can cause pulmonary edema; ACGIH accepted tolerance level: 1 ppm (1 mg/m³) of air (195).

Synthesis:

(1) 6LiH + 8BF₃ · O(C₂H₅)₂ → B₂H₆ + 6LiBF₄ + 8(C₂H₅)₂O (80)

(2) 3LiBH₄ + 4BF₃ · O(C₂H₅)₂ → 2B₂H₆ + 3LiBF₄ + 4(C₂H₅)₂O (80)

(3) 6NaH + 2BCl₃ + 6AlCl₃ benzene → B₂H₆ + 6NaAlCl₄ (16)

(4) heat 2gs of a pearl shaped mixture of boron and sodium metaborate in the molecular ratio

3 : 1 with a hydrogen stream flowing through the reaction container at the rate of 2 l/min at atmospheric pressure and 1000°C (2)

(5) HCHO + 2BBr₃ $\xrightarrow[\text{Cu}]{400^\circ\text{C}}$ B₂H₆ + HBr + CO + side products (21)

Unique conditions, reaction products:

When heated to decomposition emits dangerous boron oxide fumes, yields hydrogen when in contact with water or steam (195). Diborane may be spontaneously flammable due to the presence of penta-borane as a decomposition product (236). It reacts spontaneously with chlorine and forms spontaneously flammable hydrides with aluminum and lithium (143).

Ignition temperature:

Autoignition temperature; 100 - 125°F (142)

Flammability limits: .9 - 98% (142)

Solubility:

sl. s. cold H₂O (d. to H₃BO₃ and H₂); s NH₄OH, concentrated H₂SO₄ (80)

Handling:

Protect from physical damage, keep refrigerated (under 68°F), keep well ventilated, containers should be clean, dry and free of oxygen, store away from halogens and oxidizing agents, protect from sparks, open flames and other heat sources (142).

Thermodynamic properties:

dipole moment: 0 debye (179)

heat of combustion: 481.9 kcal/mol (221)

heat capacity (at 25°C): 13.30 cal/°mol (221)

heat of vaporization: 3.685 cal/mol (179)

heat of formation: -44 ± 3 kcal/mol (179)

critical temperature: 16.7 ± .02°C (179)

critical pressure: 581 ± 5 psia (179)

entropy (at 25°C): 55.34 cal/°mol (221)

free energy of formation (at 25°C): 19.78 kcal/mol (221)

Military and industrial uses:

Used in organic synthesis for hydrating double bonds and obtaining cis addition (132); used as fuel in air-breathing engines and rockets, as a reducing agent and in the synthesis of organic boron compounds (192).

Flammability:

Spontaneously flammable in moist air at room temperature (142).

DISILYAMINO DIBORANE

Mol. Wt.:

102.92

Formula:

B₂H₅N(SiH₃)₂

Characteristics:

Liquid - straw (226).

M. P.:

-68.8°C (226)

B. P.:

54°C (226)

V.P.:

7.974-1669/T; 162° (226)

Solubility:

s. organic solvent; d. H₂O (226)

Thermodynamic properties:

heat of vaporization (at 54°C): 7640 cal/mol (226)

Flammability:

Spontaneously flammable (226).

TETRABORANE

Mol. Wt.:

53.36

Formula:

B₄H₁₀

Synonyms:

dihydrotetraborane

borobutane

tetraboron decahydride

boron hydride

M. P.:

-120°C (226)

Characteristics:

Gas - colorless (226)

d./sp. gr.:

.56-35 (226)

B. P.:

16°C (226)

V.P.:

580°, 388° (79)

Toxicity:

High (acute local) on inhalation (195); high (acute systemic) on inhalation (195).

Synthesis:

Precipitated from reaction of magnesium boride with HCl or phosphoric acid (132).

Unique conditions, reaction products:

Forms boric acid and hydrogen on reacting with H_2O ; forms tetraammoniate from NH_3 (132).

Solubility:

d. H_2O (226), alcohol (79)

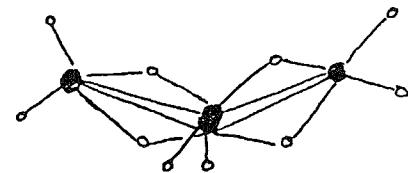
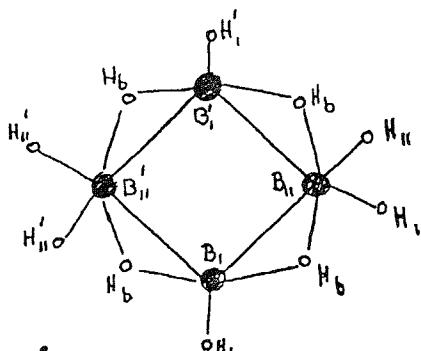
Thermodynamic properties:

heat of vaporization: 6.47 kcal/mol (226)

Flammability:

Spontaneously flammable in air (226).

Structure:



$$B_1 - B_{11} = 1842 \text{ \AA}$$

$$B_1 - B_{1'} = 1.712 \text{ \AA}$$

$$B_{11} - B_{1'} = 2.800 \text{ \AA}$$

$$B - H = 1.10 \text{ \AA} \quad (174)$$

$$B_1 - H_b = 1.16 \text{ \AA}$$

$$B_{11} - H_b = 1.37 \text{ \AA}$$

PENTABORANE

(Stable)

Mol. Wt.:

63.13

Formula:

B_5H_9

Synonyms:

Pentaboron enneahydride

M. P.:

-46.82°C (79)

Characteristics:

Gas - colorless, bad odor

V. P.:

66° (195)

d./sp. gr.:

.66° (79)

n^{24}

D: (49)
1.4445

V. d.:

2.2 (195)

B. P.:

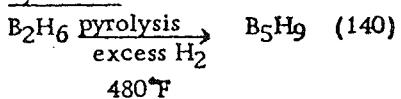
58.4°C (79)

Toxicity:

Maximum tolerance .005 ppm (.01 mg/m³) (195); an hour after a 1½ minute exposure to pentaborane during a disposal operation the men experienced psychomotor function difficulties, memory

blocking, lack of coordination, feelings of detachment ("classic" systems of boron toxicosis) irrationality loss followed for four days (8).

Synthesis:



Unique conditions, reaction products:

Hydrolyzes slowly in H_2O at room temperature, will react with any organic compound containing a reducible functional group, reacts with hydrogen and other amines, react with ClF_3 to yield hypergolic ignition and intense fireballs (152); large explosion with hydrazine (189).

Solubility:

- d. cold H_2O ; s: without reaction in hydrocarbon solvents (e.g., kerosene, hexane, benzene, toluene)
- s. in oxygenated or halogenated solvents — but forms shock sensitive mixture (152).

Ignition temperature:

Spontaneously ignites at 65.5°C (67)

Lean limit of spontaneous ignition: 14% (vol) at 1 atmosphere and 55% at .1 atmosphere (188)

Rich limit of spontaneous ignition: not determined but 75% ignites at 5 cm mercury (183)

Handling:

Can be stored for at least 3 years in a clean moisture free vessel under an inert atmosphere (140).

Thermodynamic properties:

heat of combustion: 1003 kcal/mol (221)

heat of formation (at 25°C) (gas): 15.02 kcal/mol (221)

heat of formation (liq): 7.72 kcal/mol (221)

free energy of formation (at 25°C) (gas): 39.32 kcal/mol (221)

free energy of formation (liq): 38.56 kcal/mol (221)

entropy (at 25°C) (gas): 65.95 cal/°mol (221)

entropy (liq): 44.03 cal/°mol (221)

heat capacity (at 25°C) (gas): 23.52 cal/°mol (221)

heat capacity (liq): 36.12 cal/°mol (221)

dipole moment (at -60.2°F): 4.54 debye (105)

heat of vaporization (at -72.4°F): 13,860 Btu/lb mol (105)

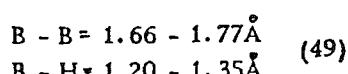
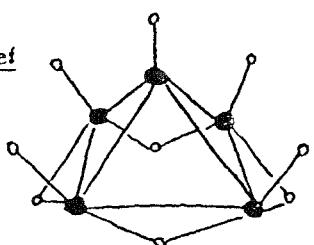
Military and industrial uses:

Liquid rocket fuel (140).

Flammability:

Spontaneously flammable (195); pyrophoric tendencies may be due to contamination by diborane (28); high humidity decreases likelihood of B_5H_9 air reaction (49).

Structure:



PENTABORANE
(Unstable)

Mol. Wt.:
65.2

Formula:
 B_5H_{11}

Synonyms:
Dihydropentaborane

M. P.:
-123°C (132)

Characteristics:
Liquid - colorless, turns yellow on standing (195)

V.P.:
52.8°; 7.2-33.4 (226)

B.P.:
63°C (195)

Toxicity:

Tolerance: .005 ppm (.01 mg/m³ air) (195)

Unique conditions, reaction products:

On standing for a long period of time or heating, it produces diborane, tetraborane, hydrogen, pentaborane, decaborane and brown nonvolatile liquids and solids; hydrolyzes in water to boric acid and hydrogen, reacts with ammonia to form tetraammoniate (132).

Solubility:

d. alcohol, air (226)

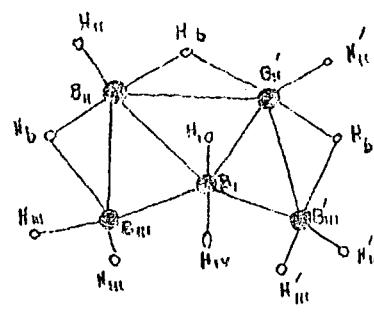
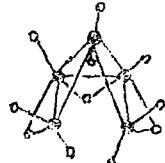
Thermodynamic properties:

heat of vaporization: 7.61 kcal/mol (226).

Flammability:

Spontaneously flammable (226).

Structure:



$B_1 - B_{11} = 1.72\text{\AA}$
 $B_1 - B_{111} = 1.87\text{\AA}$
 $B_{11} - B_{111} = 1.76\text{\AA}$
 $B_{11} - B'_{11} = 1.77\text{\AA}$
 Ave B - H = 1.10\text{\AA}
 Ave B - H_b = 1.22\text{\AA}
 $B_1 - H_{1v} = 1.09\text{\AA}$
 $B_{111} - H_{1v'} = 1.72\text{\AA}$
 Angle $B_{111} - B_{11} - B'_{11}$ is 112°

{ (174)

HEXABORANE

Mol. Wt.:
75.00

Formula:
 B_6H_{10}

Synonyms:
Boron hydride
Hexaboron decahydride

M. P.:
-65°C (226)

Characteristics:
Liquid - colorless (226)

V.P.:
70 (226)

d./sp. gr.:
.69 (226)

B.P.:
110°C (226)

V.d.:
2.6 (195)

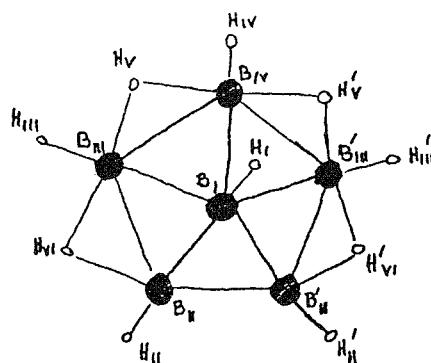
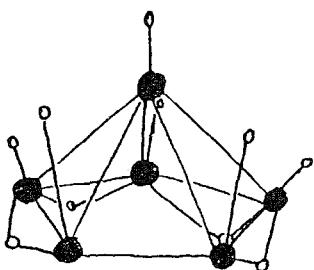
Solubility:

d. H₂O, alcohol (226)

Flammability:

Spontaneously flammable (226).

Structure:



(174)

$$\begin{aligned}
 B_1 - B_{11} &= 1.795 \pm .010 \text{\AA} \\
 B_1 - B_{111} &= 1.753 \pm .009 \text{\AA} \\
 B_1 - B_{1V} &= 1.740 \pm .014 \text{\AA} \\
 B_{11} - B'_{11} &= 1.596 \pm .012 \text{\AA} \\
 B_{11} - B_{111} &= 1.737 \pm .010 \text{\AA} \\
 B_{111} - B'_{1V} &= 1.794 \pm .009 \text{\AA} \\
 B_1 - H_1 &= 1.25 \pm .06 \text{\AA} \\
 B_{11} - H_{11} &= 1.28 \pm .05 \text{\AA} \\
 B_{11} - H_{V1} &= 1.36 \pm .04 \text{\AA} \\
 B_{111} - H_{111} &= 1.18 \pm .04 \text{\AA} \\
 B_{111} - H_{V1} &= 1.31 \pm .04 \text{\AA} \\
 B_{111} - H_V &= 1.48 \pm .05 \text{\AA} \\
 B_{1V} - H_{1V} &= 1.14 \pm .06 \text{\AA} \\
 B_{1V} - H_V &= 1.32 \pm .06 \text{\AA}
 \end{aligned}$$

DIHYDROHEXABORANE

Mol. Wt.:

77.02

Formula:

B₆H₁₂

M. P.:

-90°C (226)

Characteristics:

Liquid - colorless,
unstable (226)

B.P.:

d. 20°C (226)

Solubility:

d. alcohol; s. organic solvent (226)

Flammability:

Spontaneously flammable (226).

DECABORANE

Mol. Wt.:

122.22

Formula:

B₁₀H₁₄

Synonyms:

Boron hydride

Decaboron tetradicahydride

M. P.:

99.5°C (226)

Characteristics:

Solid - white, crystal (226)

d./sp. gr.:

.94²⁵ (226)

B.P.:

213°C (226)

V.P.:

19100 (226)

Toxicity:

High as irritant, and on inhalation tolerance .05 ppm (.3 mg/m³) air (195).

Solubility:

s. cold H₂O; d. hot H₂O; s. alcohol, ether, benzene (79)

Thermodynamic properties:

standard heat of formation: 8 kcal/mol (79)

heat of combustion: 1950 kcal/mol (79)

free energy of formation:

gas
71 kcal/mol

liquid
65 kcal/mol

standard entropy:

15.09 e.u.

42.20 e.u.

heat capacity:

40.0 cal/^omol

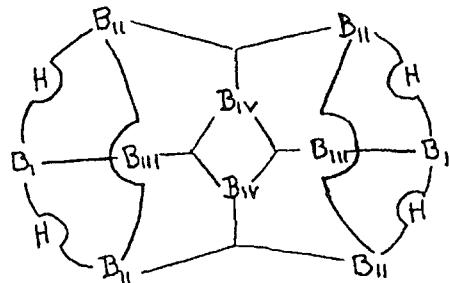
52.09 cal/^omol

} (79)

Flammability:

Spontaneously flammable in air or O₂ (143).

Structure:



Each B atom is two center bonded to a hydrogen atom (not shown in diagram) (174)

BARIUM HYDRIDE

Mol. Wt.:

139.38

Formula:

BaH₂

M. P.:

d. 675°C (79)

Characteristics:

Solid - gray crystal lumps (79)

d./sp. gr.:

4.21 (226)

B. P.:

1400°C (79)

Unique conditions, reaction products:

Vigorous reaction with H₂O (91)

Solubility:

d. cold H₂O to Ba(OH)₂, d. acid (79)

Thermodynamic properties:

heat of formation: 40.96 kcal/mol (226)

free energy of formation: -31.6 kcal/mol (32)

entropy (at 208°C): 16 cal/^omol (32)

Military and industrial uses:

Used as a reducing agent and as condensation and reducing agent for organic reactions (91).

Flammability:

If finely powdered spontaneously ignites in moist air, possible also to spontaneously ignite in dry air (91).

BERYLLIUM BOROHYDRIDE

Mol. Wt.:
38.72

Formula:
 $\text{Be}(\text{BH}_4)_2$

Synonyms:
Beryllium bis(tetrahydroboron)

M. P.:
d. 123°C (226)

V.P.:
.50 (226)

Unique conditions, reaction products:

Vigorous reaction with water and other reducing agents (226); reacts with water to yield heat and hydrogen (195); explosive reaction with H_2O or O_2 (220).

Solubility:

s. organic solvents, including non-polar solvents such as benzene (226).

Thermodynamic properties:

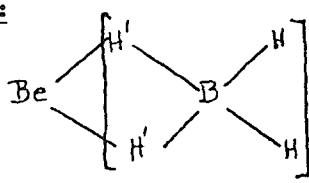
heat of sublimation: 14,820 cal/g mol
heat of vaporization: 14,810 cal/mol
heat of formation: 98 kcal/mol
heat of combustion: 16.7 kcal/mol

} (103)

Flammability:

Spontaneously flammable in air (226).

Structure:



$\text{Be} - \text{B} = 1.74\text{\AA}$
 $\text{Be} - \text{H}' = 1.63\text{\AA}$
 $\text{B} - \text{H}' = 1.28\text{\AA}$
 $\text{B} - \text{H} = 1.22\text{\AA}$

} (174)

BERYLLIUM HYDRIDE

Mol. Wt.:
11.03

Formula:
 BeH_2

M. P.:
d. 125°C (226)

Characteristics:
Solid - white (226)

Synthesis:

- (1) $\text{Be}(\text{CH}_3)_2 + \text{LiAlH}_4 \xrightarrow{\text{Et}_2\text{O}} \text{BeH}_2 + \text{LiAlH}_2(\text{CH}_3)_2$ (ether of composition not removable) (134)
 (2) $\text{Be}(\text{C}_4\text{H}_9)_2 \xrightarrow{\Delta} \text{BeH}_2 + 2\text{C}_4\text{H}_8$ (134)

Unique conditions, reaction products:

Reacts with water, dilute acid, CH_3OH to yield H_2 (195).

Solubility:

i. ether, toluene, isopentane (226)

in dry

M. P.:

> 1000°C (226)

816°C in hydrogen (195)

Formula:

CaH₂

d./sp. gr.:

1.9 (226)

Characteristics:

Solid - white crystals (226)

B.P.:

d. 1000°C (133)

d. 600°C (195)

Synthesis:

Heat parent metal in hydrogen atmosphere at 200°-300°C (133); reduce lime in presence of hydrogen with magnesium (132).

Solubility:

d. with H₂O, lower alcohols, and carboxylic acids to form H₂ (132)

Thermodynamic properties:

heat of formation: 46.6 kcal/mol (226)

Military and industrial uses:

To generate H₂ (1g CaH₂ in H₂O → 1 l H₂ at STP), preparation of rare metals by reduction of their oxides, as a drying agent for liquids and gases (132).

Flammability:

Calcium hydride "less likely" to ignite in water than NaH, LiAlH₄ or NaAlH₄, may have dust explosion if finely dispersed in air (133).

CERIUM (III) ALUMINOHYDRIDE

Mol. Wt.:

233.07

Formula:

Ce(AlH₄)₃

M. P.:

d. -80°C (13)

Synthesis:

From the solid complex with LiBr; treat the complex with LiAlH₄ near freezing point of the ether; a precipitate of the aluminohydride is yielded (13).

Flammability:

Spontaneously flammable (13).

e (134)

CERIUM HYDRIDE

Mol. Wt.:

143.14

Formula:

CeH₃

Synonyms:

Trihydrocerine, cerous hydride

M. P.:
d. 1080°C (226)

Characteristics:
Solid - black powder (226)

V. P.:
.5450-500 (226)

d./sp. gr.:
5.5 (226)

Solubility:
d. air, H₂O (226)

Thermodynamic properties:
heat of formation: 42.26 kcal/mol (226)

Flammability:
Spontaneously flammable (226).

COBALT TRIPHOSPHINE

Mol. Wt.:
157.85

Formula:
Co(PH₂)₃

Flammability:
Spontaneously flammable (240).

CESIUM HYDRIDE

Mol. Wt.:
133.92

Formula:
CsH

M.P.:
decomposes (79)

Characteristics:
Solid - white, cubic
crystalline (79)

d./sp. gr.:
2.7 (195)
3.41 (79)

Synthesis:
Cs + 1/2H₂ → CsH (80)

Solubility:
d. hot and cold H₂O, alcohol; i. organic solvents (79)

Thermodynamic properties:

heat of formation:

gas
29.0 kcal/mol

crystalline
-10.1 kcal/mol

free energy of formation:

24.3 kcal/mol

-7.3 kcal/mol (at 9°C)

entropy:

51.25 cal/°mol

20.8 cal/°mol (at 102 mm)

} (31)

Flammability:

Ignites in oxygen at room temperature (80).

COPPER ALUMINOHYDRIDE

Mol. Wt.: 94.52 Formula: CuAlH₄

M. P.:
d. -70°C (13)

Synthesis

Form a solid complex with LiBr then treat with LiAlH₄ near the freezing point of ether and a precipitate of aluminohydride is yielded (13).

Flammability:

Spontaneously flammable (13).

COPPERHYDRIDE

Mol. Wt.: 64.55 Formula: CuH

M. P.:
d. slowly 55°-60°C (103) Characteristics:
Red - brown (103)

d./sp. gr.:
6.38 (103)

Solubility:
i. cold H₂O; d. hot H₂O, HCl (103)

Thermodynamic properties:

standard heat of formation: 71 kcal/mol
standard free energy of formation: 64 kcal/mol
standard entropy: 46.89 cal/*mol } (79)

Flammability:

Spontaneously flammable in air when dry (234).

GALLIUM HYDRIDE

Mol. Wt.: 145.49 Formula: Ga₂H₆ Synonyms: Digallane

M. P.:
-21.4°C (226) Characteristics:
Liquid - colorless (226) V.P.:
2.50, 700130 (226)

B.P.:
139°C (extrapolated) (226)

} mm) }

Synthesis:Flammability:

Probably spontaneously flammable (93).

TGA
GERMANIUM HYDRIDE

Mol. Wt.:
76.62

Formula:
 GeH_4

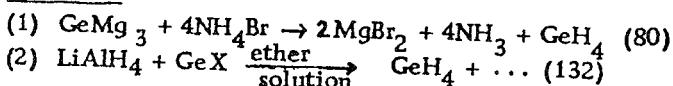
Synonyms:
Germane

M. P.:
-165°C (79)

Characteristics:
Gas - colorless (79)

B.P.:
-88.5°C, d. 350°C (79)

d./sp. gr.:
1.523-142 (79)

Synthesis:Solubility:

i. hot and cold H_2O ; s. liquid NH_3 , NaOCl (79)

Thermodynamic properties:

enthalpy: $-22.2 \pm .5 \text{ kcal/mol}$ (78)

heat of formation: $21.6 \pm .5 \text{ kcal/mol}$ (78)

Flammability:

Decomposes in air often bursting into flames (80).

GERMANIUM HYDRIDE

Mol. Wt.:
151.25

Formula:
 Ge_2H_6

Synonyms:
Digermane

M. P.:
-109°C (79)

Characteristics:
Liquid (79)

B.P.:
29°C (79)

d./sp. gr.:
1.98-109 (79)

Synthesis:Solubility:

d. cold H_2O ; s. liquid NH_3 (79)

Thermodynamic properties:

heat of formation: 38.7 ± 3 kcal/mol (78)

Flammability:

Decomposes in air often bursting into flames (80).

GERMANIUM HYDRIDE

Mol. Wt.:
225.83

Formula:
 Ge_3H_8

Synonyms:
Trigermane

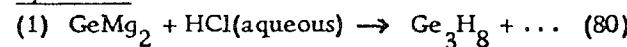
M. P.:
-105.6°C (79)

Characteristics:
Liquid - colorless (79)

B.P.:
110.5°C (d. 195°C) (79)

d./sp. gr.:
2.2²⁰ (79)

Synthesis:



Solubility:

i. hot and cold H_2O ; s. CCl_4 (79)

Flammability:

Decomposes in air often bursting into flames (80).

SODIUM HYDRIDE

Mol. Wt.:
24.00

Formula:
 NaH

d./sp. gr.:
1.396 (226)

M. P.:
d. 800°C (79)

Characteristics:
Solid - gray white
crystal powder (226)

n_D:
1.470 (79)

Toxicity:

High (195)

Synthesis:

Pass hydrogen into molten sodium dispersed in oil or mixed with a catalyst such as anthracene (above 250°C) (132).

Unique conditions, reaction products:

NaH more reactive with H_2O than Na is (226); violent reaction with lower alcohols (132).

Solubility:

s. molten NaOH ; i. liquid NH_3 (132)

Thermodynamic properties:

	<u>gas</u>	<u>cyrstalline</u>	
standard heat of formation:	29.88 kcal/mol	-13.60 ± .24 kcal/mol (at 101°C)	
standard free energy of formation:	27.78 kcal/mol	-9.0 kcal/mol (at 90°C)	
entropy:	44.93 cal/°mol	7.1 cal/°mol (at 102°C)	{(31)}

Military and industrial uses:

Powerful reducing agent (132).

Flammability:

Finely powdered, spontaneously flammable in moist air (226).

SODIUM PHOSPHAMIDE

Mol. Wt.:

99.94

Formula:NaPH₂Synthesis:

Pass hydrogen phosphide into solution of sodammonium in liquified ammonia, the gas is absorbed and hydrogen is evolved (quantity of H₂O generated corresponds to the formation of NaPH₂). A liquid is formed which does not mix with the ammonia although it is not quite insoluble in it, the liquid solidifies when slowly cooled (131).

Flammability:

Spontaneously flammable (200).

HAFNIUM BOROHYDRIDE

Mol. Wt.:

197.32

Formula:HF(BH₄)₄M. P.:

29.0°C (71)

Characteristics:

Solid - volatile (71)

B. P.:

118°C (extrapolated) (71)

Unique conditions, reaction products:

Similar to aluminum borohydride, most volatile of known hafnium compounds (71).

Flammability:

Like the borohydrides of Al, Be, Zr, hafnium borohydride inflames violently when exposed to air (71).

POTASSIUM HYDRIDE

Mol. Wt.:

40.11

Formula:

KH

M. P.:

Decomposes (79)

Characteristics:

Solid - white needles (79)

n

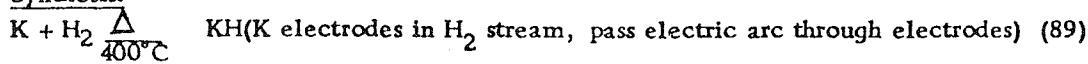
D:

1.453 (79)

d. /sp. gr.:

1.47 (79)

Synthesis:



Unique conditions, reaction products:

Reacts with steam or water, or acids to produce H_2 , vigorously reacts with oxidizing materials (195).

Solubility:

d. hot and cold H_2O ; i. CS_2 , ether, benzene (79).

Thermodynamic properties:

	<u>gas</u>	<u>crystalline</u>
heat of formation:	30.0 kcal/mol	$15.15 \pm .16$ kcal/mol
free energy of formation:	25.1 kcal/mol	(90°C) -8.9 kcal/mol (31)
entropy:	47.3 cal/ $^\circ$ mol	(102 mm) 10.2 cal/ $^\circ$ mol

Flammability:

Ignites at lower temperature than NaH (39), spontaneously flammable (50).

LITHIUM ALUMINUM DEUTERIDE

d./sp. gr.:

1.029/cm³ (195)

Formula:

LiAlD₄

B.P.:

d. 124°C (195)

Unique conditions, reaction products:

React aluminum chloride with lithium deuteride (190).

Flammability:

Spontaneously flammable in air (195).

LITHIUM ALUMINUM HYDRIDE

Mol. Wt.:

37.95

Formula:

LiAlH₄

M. P.:

d. 125°C (79)

Characteristics:

Solid - white crystalline powder (79)

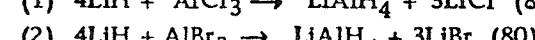
d./sp. gr.:

.917 (79)

Toxicity:

Highly caustic on inhalation, ingestion and on skin contact (142).

Synthesis:



Unique conditions, reaction products:

With water and acids yields hydrogen and heat enough to cause ignition (142).

Handling:

Ship in air tight metal container, glass bottle or polyethylene bags in metal containers, steel or fiber drums; protect from physical damage, store in cool dry area (142).

Thermodynamic properties:

heat of formation -24.08 kcal/mol

heat of formation (at 25°C) -165.87 kcal/mol (45)

Military and industrial uses:

Powerful reducing agent for organic compounds (68).

Flammability:

Spontaneously flammable in H₂O (68).

LITHIUM ALUMINUM TRI-TERT-BUTOXYHYDRIDE

Mol. Wt.:

254.04

Formula:

LiAl[OC(CH₃)₃]₃H

Synonyms:

LATB

lithium tri-tert-butoxyaluminahydride

M. P.:

d. > 400°C (190)

Characteristics:

Solid - white powder (190)

d./sp. gr.:

1.03 (190)

Solubility:

s. dimethyl ether of diethylene glycol, tetrahydrofuran, diethyl ether (190)

Military and industrial uses:

Stereospecific reductions of steroid ketones; reduction of acid chlorides to aldehydes (190).

Flammability:

"Reacts with H₂O to evolve H₂, usually does not ignite" (190).

LITHIUM BOROHYDRIDE

Mol. Wt.:

21.78

Formula:

LiBH₄

M. P.:

d. 279°C (79)

Characteristics:

Solid - rhombic crystals,
white cubic crystals (79)

d./sp. gr.:

.66 (79)

Synthesis:

- (1) $4\text{LiH} + \text{BF}_3 \cdot \text{O}(\text{C}_2\text{H}_5)_2 \rightarrow \text{LiBH}_4 + 3\text{LiF} + \text{O}(\text{C}_2\text{H}_5)_2$ (80)
 (2) $2\text{LiH} + \text{B}_2\text{H}_6 \rightarrow 2\text{LiBH}_4$ (80)

Solubility:

v. sl. s. cold H_2O (79)

Thermodynamic properties:

heat of combustion: 136.000 cal/g mol (107)

enthalpy (at 25°C): -74.51 kcal/mol (45)

heat of formation (at 25°C): -72.14 kcal/mol (45)

heat of formation (at 298.16°C): -44.15 kcal/mol (45)

Military and industrial uses:

Source of hydrogen and of other borohydrides, reducing agent for aldehydes, ketones and esters (190).

Flammability:

May ignite on contact with H_2O or in moist air (69).

LITHIUM HYDRIDE

Mol. Wt.:

7.95

Formula:

LiH

M. P.:

680°C (79)

Characteristics:

Solid - white crystals (79)

d. / sp. gr.:

.82 (79)

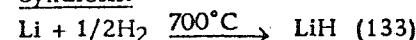
B.P.:

d. 850°C (133)

Toxicity:

Tolerance level - .025 mg/m³ (195).

Synthesis:



Unique conditions, reaction products:

Reacts with alcohol, carboxylic acids, chlorine and ammonia at 400°C to liberate hydrogen (132).

Solubility:

d. cold H_2O ; v. sl. s. acid (79)

Handling:

Immerse in mineral oil or paraffin wax (160).

Thermodynamic properties:

high frequency dielectric constant: 3.61 (159)

lattice constant: 4.0835A (159)

lattice energy (Born-Haber cycle): 218.8 kcal/mol (159)

	<u>gas</u>	<u>crystalline</u>	<u>(30)</u>
entropy (at 25°C):	40.77 cal/*mol	5 cal/*mol	
free energy of formation (at 25°C):	25.2 kcal/mol	-16.72 kcal/mol	

heat of formation (at 25°C) 30.7 kcal/mol

-21.34 ± .15 kcal/mol

Military and industrial uses:

Used as a desiccant, source of H₂, condensing agent with ketones and acid esters (132).

Flammability:

Can ignite spontaneously in moist air (195).

MAGNESIUM HYDRIDE

Mol. Wt.:

26.33

Formula:

MgH₂

M.P.:

d. 280°C (79)

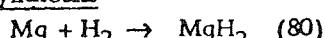
Characteristics:

Solid - white tetragonal crystal or mass (79)

d./sp. gr.:

1.419 (79)

Synthesis:



Unique conditions, reaction products:

Violent reaction with H₂O (MgH₂ + 2H₂O → Mg(OH)₂ + H₂) (132).

Solubility:

Violent d. cold H₂O; i. ether (79).

Thermodynamic properties:

heat of formation (at 298°C): -21.71 ± .65 kcal/mol (161).

Flammability:

Ignites spontaneously with air to yield MgO + H₂O; also ignites with tap water but not in distilled H₂O (132).

MANGANESE (II) ALUMINOHYDRIDE

Mol. Wt.:

116.90

Formula:

Mn(AlH₄)₂

M.P.:

d. -80°C (13)

Synthesis:

Form solid complex with LiBr, heat complex with LiAlH₄ near freezing point of ether, yields a precipitate of aluminohydride (13).

Flammability:

Spontaneously flammable (13)

(30)
TRISILICYLAMINE

Mol. Wt.:

107.34

Formula:

$(SiH_3)_3N$

Synonyms:

Nitrido - Tri - silane

Trisilyamine

Nitrosilane

M.P.:

-105.6°C (226)

Characteristics:

Liquid - colorless (226)

d./sp. gr.:

.895-10⁶ (226)

B.P.:

52°C (226)

Unique conditions, reaction products:

Reacts with H₂O or steam to produce flammable vapors (94).

Solubility:

s. organic solvent (226)

Flammability:

Spontaneously flammable (226).

SODIUM ALUMINUM HYDRIDE

Mol. Wt.:

54.00

Formula:

NaAlH₄

M.P.:

d. 183°C (190)

d./sp. gr.:

1.24 g/cc (190)

d. 230°C (133)

Synthesis:

React AlCl with NaH (190)

Thermodynamic properties:

heat of formation (at 25°C): 13.5 kcal/mol (190)

free energy of formation (at 25°C): 3.0 kcal/mol (190)

Military and industrial uses:

Used to reduce carbonyl and carboxyl groups to hydroxyl groups, to reduce amides to amines and to reduce organic halides to hydrocarbons (133).

Flammability:

Fire and possible explosion if water, as liquid or vapor comes in contact with (133).

DIPHOSPHINE

Mol. Wt.:
65.98

Formula:
 PH_2 or P_2H_4

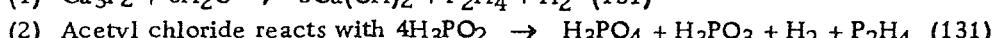
M. P.:
-99°C (226)

Characteristics:
Liquid - colorless (79)

d./sp. gr.:
1.012 (79)

B. P.:
51.7°C (226)

Synthesis:



Solubility:

i. hot and cold H_2O ; s. alcohol, turpentine (79)

Thermodynamic properties:

heat of vaporization: 6.89 kcal (231)

trouton's constant: 21 (231)

Flammability:

Spontaneously flammable in air (143).

PHOSPHINE

Mol. Wt.:
34.00

Formula:
 PH_3

Synonyms:

Hydrogenphosphide

Phosphoretted hydrogen

Phosphorus trihydride

M. P.:
-133.5°C (226)

Characteristics:
Gas - colorless (226)

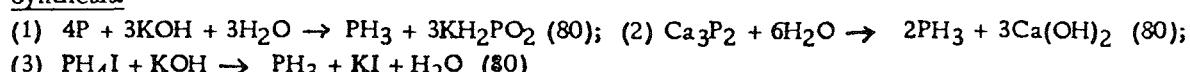
d./sp. gr.:
1.317¹ (226)
1.529⁰ (226)

B. P.:
-87.4°C (226)

Toxicity:

Moderate; high on inhalation, moderate as irritant; tolerance .05 ppm (.07 mg/m³ air); central nervous system depressant; irritates lungs, dilates heart, can cause hyperemia of visceral organs (195).

Synthesis:



Unique conditions, reaction products:

Emits highly toxic phosphorus fumes when heated to decomposition (195); reacts with concentrated HNO_3 with violent decomposition and flames; spontaneous ignition in presence of nitrous acid (143).

Ignition temperature:

Autoignition temperature: 40°-65°C (97).

Solubility:

sl. s. H₂O; s. alcohol, ether (226)

Thermodynamic properties:

heat of formation: 2.3 kcal/mol (226)

entropy (at 25°C): 50.23 cal/°mol (226)

enthalpy: -1.6 ± .4 (78)

Flammability:

Spontaneously flammable (226)

TRISILYL PHOSPHINE

Mol. Wt.:
124.32

Formula:
P(SiH₃)₃

Characteristics:

Liquid - colorless (226)

V.P.:

83 mm (at 0°C) (226)

Solubility:

d. H₂O; s. organic solvent (226).

Flammability:

Spontaneously flammable (226).

PLUTONIUM HYDRIDE

Mol. Wt.:
244.02

Formula:
PuH₂

d./sp. gr.:
10.4 (103)

Characteristics:
Solid - cubic (103)

Thermodynamic properties:

heat of formation (at 70°C): -37.0 kcal/mol (23)

Flammability:

Spontaneously flammable (137).

RUBIDIUM HYDRIDE

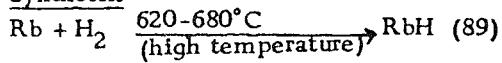
Mol. Wt.:
86.48

Formula:
RbH

M.P.:
d. 300°C (79)

Characteristics:
Solid - colorless needles (79)

d./sp. gr.:
2.60 (79)

Synthesis:Unique conditions, reaction products:Violent reaction with H_2O (89)Solubility:i. organic solvents (89); d. cold and hot H_2O , acid (79)Thermodynamic properties:

heat of formation:	<u>gas</u> 33.0 kcal/mol	<u>crystalline</u> -11.3 kcal/mol (at 102°C) (31)
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Military and industrial uses:

Used as light sensitive element for photocells (89).

Flammability:

Ignites on contact with air due to exothermic reaction of hydride with moisture (89).

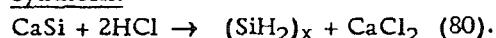
SILICON HYDRIDES

Mol. Wt.: $(30 \cdot 10)_x$ Formula: $(\text{SiH}_2)_x$ Synonyms:

Polysilanes

Toxicity:

High (acute local) as irritant, on ingestion and on inhalation (195).

Synthesis:Unique conditions, reaction products:

Reacts with alkali hydroxides to yield hydrogen (80).

Flammability:Spontaneously flammable in air leaving SiO_2 residue (80).

SILANE

Mol. Wt.:

32.12

Formula: SiH_4 Synonyms:

Silicon tetrahydride

Silicon hydride

Silicane

M.P.: -185°C (226)Characteristics:

Gas - colorless (226)

d./sp. gr.:

(liq) .68 -185 (226)

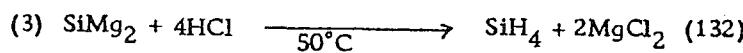
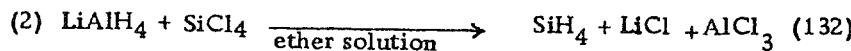
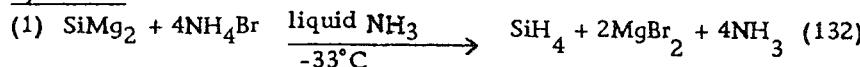
(gas) 1.44 (195)

B.P.: -111.8°C (226)

Toxicity:

High (acute local) as irritant, on ingestion or on inhalation (195).

Synthesis:



Solubility:

d. air, alkaline solvent; s. organic solvent (226)

Thermodynamic properties:

heat of formation: 11.9 kcal/mol (226)

Flammability:

Spontaneously flammable (226)

SILYL PHOSPHINE

Mol. Wt.:

64.11

Formula:

H_3SiPH_2

Synonyms:

Phosphinyl Silane

M. P.:

< -185°C (99)

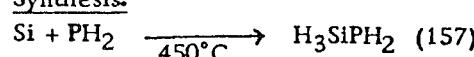
Characteristics:

Liquid (79)

B. P.:

12.7°C (extrapolated) (53)

Synthesis:



Solubility:

d. alkaline solvents (79)

Flammability:

Thermally stable to 400°C but ignites if traces of O_2 are present (157)

OXADISILANE

Mol. Wt.:

76.18

Formula:

H_3SiSiHO

Flammability:

Spontaneously flammable in air (143).

DISILANE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
62.23	Si ₂ H ₆	Silicoethane
<u>M. P.:</u>	<u>Characteristics:</u>	
-132.5°C (226)	Gas - colorless (226)	
<u>d./sp. gr.:</u>	<u>B.P.:</u>	
.686 ²⁵ (226)	-15°C (226)	

Unique conditions, reaction products:

Explodes with SF₆; reacts violently with CCl₄ and chloroform (136).

Solubility:

s. organic solvent; d. alkaline solvent (226)

Thermodynamic properties:

enthalpy: -18.3 ± .3 kcal/mol (78)

heat of formation: 17.4 ± 0.3 kcal/mol (78); -35.8 kcal/mol (59)

heat of combustion: -575.3 kcal/mol (at 293°K) (60)

enthalpy of formation: -36.2 kcal/mol (at 293°K) (60)

Flammability:

Spontaneously flammable (226).

TRISILANE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
92.33	Si ₃ H ₈	Trisilicon octahydride Trisilane propane Silicon hydride
<u>M. P.:</u>	<u>Characteristics:</u>	
-117.4°C (226)	Liquid - colorless (226)	
<u>d./sp. gr.:</u>	<u>B.P.:</u>	<u>V.P.:</u>
.743 ⁰ (226)	53°C (226)	95.50 ⁰ (195)
.725 ²⁵ (226)		

Solubility:

s. organic solvent; d. H₂O, CCl₄ (226)

Thermodynamic properties:

enthalpy of formation; -54.4 kcal/mol (60)

heat of formation: -54.1 kcal/mol (59)

heat of combustion (at 293°K): -835.1 ± 7 kcal/mol (60)

Flammability:

Spontaneously flammable (226).

SILOXANE

<u>Mol. Wt.:</u> 222.56	<u>Formula:</u> $\text{Si}_6\text{O}_3\text{H}_6$	<u>Synonyms:</u> Hexaoxocyclosilane
<u>M.P.:</u> d. 140°C (79)	<u>Characteristics:</u> Solid - white platelets (79)	
<u>d./sp. gr.:</u> 1.32 ²⁰ (79)		
<u>Solubility:</u> sl. d. cold H ₂ O; slight d. hot H ₂ O (79); d. air (79)		
<u>Flammability:</u> Spontaneously flammable (50)		

STRONTIUM HYDRIDE

<u>Mol. Wt.:</u> 89.64	<u>Formula:</u> SrH_2
<u>M.P.:</u> d. 675°C (79)	<u>Characteristics:</u> Solid - white crystalline (226)
<u>d./sp. gr.:</u> 3.72 (226)	<u>B.P.:</u> Sublimes 1000°C (in H ₂) (79)
<u>Synthesis:</u> $\text{Sr} + \text{H}_2 \rightarrow \text{SrH}_2$ (80)	

Unique conditions, reaction products:
Vigorous reaction with H₂O (226)

Solubility:
d. hot and cold H₂O, alcohol (79)

Thermodynamic properties:
heat of formation: 42.2 kcal/mol (226)
free energy of formation (at 90°C): -33.1 kcal/mol (32)
entropy (at 209°C): 13 cal/°mol (32)

THORIUM HYDRIDE

<u>Mol. Wt.:</u> 235.07	<u>Formula:</u> ThH_3
	<u>Characteristics:</u> Solid - black powder (226)

Flammability:

Spontaneously flammable in air (226).

THORIUM HYDRIDE

Mol. Wt.:

943.00

Formula:

Th_4H_{15}

Flammability:

Spontaneously flammable in air (51).

URANIUM BOROHYDRIDE

Mol. Wt.:

282.53

Formula:

$\text{U}(\text{BH}_4)_3$

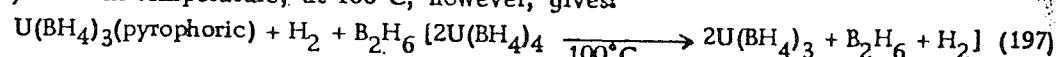
Characteristics:

Solid - brown

non volatile (197)

Toxicity:

Treat UF_4 with $\text{Al}(\text{BH}_4)_3$ at room temperature. The dark green volatile crystals of $\text{U}(\text{BH}_4)_4$ decompose very slowly at room temperature, at 100°C , however, gives



Flammability:

Spontaneously flammable and likely to detonate in air (197).

URANIUM HYDRIDE

Mol. Wt.:

241.05

Formula:

UH_2

d./sp. gr.:

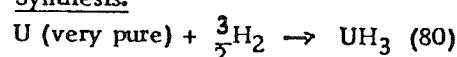
11.4 (79)

Characteristics:

Solid - black powder

cubic (79)

Synthesis:



Unique conditions, reaction products:

Powerful reducing agent; vigorous reaction with H_2O ($2\text{U}_3 + 4\text{H}_2\text{O} \rightarrow 2\text{UO}_2 + 7\text{H}_2$) (80).

Flammability:

Spontaneously flammable (80).

ZIRCONIUM BOROHYDRIDE

Mol. Wt.:

150.50

Formula:

$\text{Zr}(\text{BH}_4)_4$

M.P.:

28.7°C (71)

Characteristics:

Volatile (71)

B.P.:

123°C (71)

Flammability:

Spontaneously flammable in air (71).

ALUMINUM AMINOBOROHYDRIDES

Characteristics:

Liquid - oily (72)

Synthesis:

Aluminum borohydride reacts with $(\text{CH}_3)_2\text{NBH}_2 \rightarrow (\text{CH}_3)_2\text{NB}_2\text{H}_5$ and aminoborohydrides of aluminum (30).

Unique conditions, reaction products:

Violently attacked by air or moisture (30); reacts with diborane to yield $(\text{CH}_3)_2\text{NB}_2 + \text{Al}(\text{BH}_4)_3$ (30).

Flammability:

"Oily liquid aluminum borohydrides are spontaneously inflammable . . ." (72).

(h) NITRIDES

TRIAZIDO BORINE

Mol. Wt.:

136.82

Formula:

B(N₃)₃

Unique conditions, reaction products:

Explodes above -45°C or when added to H₂O (166).

BARIUM AZIDE

Formula:

BaN₆

Unique conditions, reaction products:

Heat in vacuum to 140-160°C → pyrophoric residue (227).

Flammability:

Spontaneously flammable (227)

CALCIUM NITRIDE

Mol. Wt.:

148.25

Formula:

Ca₃N₂

M. P.:

1195°C (79)

900°C (195)

Characteristics:

Solid - brown hexagonal
crystal (79)

d./sp. gr.:

2.6317 (79)

Synthesis:

3Ca + N₂ → Ca₃N₂ (80)

Solubility:

Evolves ammonia with moisture (195); s. dilute acid; d. absolute alcohol (79).

Thermodynamic properties:

standard heat of formation:

free energy of formation (at 25°C);

entropy (at 25°C):

crystal
-103.2 kcal/mol
-88.1 kcal/mol
25 cal/°mol } (79)

Flammability:

Spontaneously flammable in air (143).

CADMIUM NITRIDE

Mol. Wt.: 365.23 Formula: Cd₃N₂

d. / sp. gr.:
7.67 (131)

$$\text{Cd}(\text{NH}_2)_2 \xrightarrow[180^\circ\text{C}]{\Delta \text{ vacuo}} \text{Cd}_3\text{N}_2 + \text{NH}_3 \quad (162)$$

Unique conditions, reaction products

Violent explosion with H₂O (143); explodes on reaction with dilute acids and bases (131).

Thermodynamic properties:

standard heat of formation (at 25°C): crystalline 38.6 kcal/mo. (79)

CERIUM NITRIDE

Mol. Wt.: 154.12 Formula: CeN

Synthesis

Heat cerium in nitrogen (131).

Unique conditions, reaction products

With a few drops of water exothermic reaction is sufficient to ignite hydrogen and ammonia given off (142).

Thermodynamic properties

heat of formation: -78 kcal/mol (131)

entropy (at 298°K): -25.0 e.u. (131)

free energy of formation (at 298°K): -70.550 kcal/mol (131)

Flammability:

Spontaneous incandescent oxidation with moist air (143).

COPAL NITRIDE

Mol. Wt.: 72.94 Formula: CoN

Characteristics:

Synthesis:

$\text{Co}(\text{HN}_2)_3 \rightarrow \text{CoN} + 2\text{NH}_3$ (80); cobalt amide in vapor pressure eudiometer, decompose at $50^\circ - 70^\circ\text{C}$ in the absence of air (absorb evolved NH_3 on concentrated H_2SO_4) all NH_3 is eliminated yielding CoN (80).

Flammability:

Spontaneously flammable (80).

POTASSIUM NITRIDE

Mol. Wt.:

131.31

Formula:

K_2N

M. P.:

Decomposes (79)

Characteristics:

Solid - greenish black (79)

Solubility:

d. cold H_2O (79)

Flammability:

Generally spontaneously flammable in air (143).

DISULPHUR DINITRIDE

Mol. Wt.:

92.12

Formula:

S_2N_2

Characteristics:

Solid - volatile colorless crystal (80)

Synthesis:



Unique conditions, reaction products:

Explodes above 30°C in air (80).

Solubility:

s. benzene, ether, CCl_4 , acetone (80)

STRONTIUM AZIDE

Mol. Wt.:

171.63

Formula:

SrN_6

Unique conditions, reaction products:

Heat in vacuum to $140^\circ - 160^\circ\text{C} \rightarrow$ pyrophoric residue (227)

Flammability:

Spontaneously flammable (227)

at 50°[±]70°
yielding

THORIUM NITRIDE

Mol. Wt.:

752.14

Formula:

Th₃N₄

Characteristics:

Solid - dark brown powder
or black crystal (79)

Synthesis:

- (1) 3Th + 2N₂ → Th₃N₄
 (2) 3ThCl₄ + 2N₂ + 6H₂ → Th₃N₄ + 12HCl } (80)
 (3) 3ThO₂ + 6C + 2N₂ → Th₃N₄ + 6CO }

Unique conditions, reaction products:

Burns in air with incandescence (143).

Solubility:

sl. d. cold H₂O; d. hot H₂O; s. HCl (79)

AZIDO THALLIUM

Mol. Wt.:

246.39

Formula:

TlN₃

Synonyms:

Thallium azide

M. P.:

330^{vac} (79)

Characteristics:

Solid - explosive tetragonal
(79)

Unique conditions, reaction products:

Explodes in air (103).

Solubility:

i. alcohol, ether (79)

URANIUM NITRIDE

Mol. Wt.:

252.04

Formula:

UN

M. P.:

(about) 2630 ± 50°C (79)

Characteristics:

Solid - brown powder (79)

d./sp. gr.:

14.31 (79)

Synthesis:

(1) Thermal decomposition of higher nitrides of uranium in a vacuum; (2) by strongly heating mixtures of uranium and the higher nitrides; (3) reduction of higher nitrides with hydrogen; (4) direct reaction of ammonia or nitrogen with uranium hydride; or (5) direct reaction between nitrogen and uranium (131).

Thermodynamic properties:

standard heat of formation:

crystalline
-80 kcal/mol
-75 kcal/mol
18 cal/ $^{\circ}$ mol

standard free energy of formation:

} (79)

entropy (at 25 $^{\circ}$ C):

Flammability:

Spontaneously flammable (240).

(i) OXIDES

BARIUM PEROXIDE

Mol. Wt.:

169.34

Formula:

BaO₂

Synonyms:

Barium binoxide
Barium dioxide

M. P.:

450°C (79)

Characteristics:

Solid - gray white
powder (79)

d./sp. gr.:

4.96 (79)

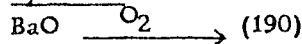
B.P.:

200°C (in O₂) (79)

Toxicity:

Slight as irritant on ingestion and on inhalation (195); threshold limiting value .5 mg/m³ (142).

Synthesis:



Unique conditions, reaction products:

Reacts with large quantities H₂O explosively (144).

Solubility:

v. sl. s. cold H₂O; d. hot H₂O; s. dilute acids; i. acetone (79)

Handling:

Protect from physical damage, keep from combustible organic or other readily oxidized materials,
keep from moisture (142).

Thermodynamic properties:

standard heat of formation: -150.5 kcal/mol (79)

transition temperature: 723°K (142).

heat of transition: 5.7 kcal/mol (142).

Military and industrial uses:

Used to manufacture oxygen and hydrogen peroxide, bleaching, tracer bullets, primer in combination with aluminum powder in aluminic thermic welding, oxygenated water (190).

CHROMOUS MONOXIDE

Mol. Wt.:

68.00 (79)

Formula:

CrO

Characteristics:

Solid - black powder (79)

Solubility:i. cold and hot H₂O, dilute HNO₃ (79)Flammability:

Spontaneously flammable (50).

CESIUM OXIDE

Mol. Wt.:

281.81

Formula:Cs₂OM. P.:

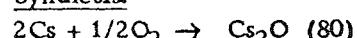
d. 400°C (79)

420°C in N₂ (79)Characteristics:

Solid - orange needles (79)

d./sp. gr.:

4.25 (79)

Synthesis:Solubility:v. s. cold H₂O; d. hot H₂O; s. acid (79)Thermodynamic properties:crystalline

standard heat of formation:

-75.9 kcal/mol (79)

entropy:

23 e.u. (79)

Flammability:Spontaneously flammable in H₂O (vigorous) (80).

FERROUS OXIDE

Mol. Wt.:

71.85

Formula:

FeO

Synonyms:

Iron oxide

M. P.:

1420°C (79)

Characteristics:

Solid - black cubic (79)

d./sp. gr.:

5.7 (79)

n

D₂

2.32 (79)

Synthesis:

(1) Thermal decomposition of iron formate or iron oxalate results in carbon bearing FeO

(FeC₂O₄ → FeO + CO + CO₂) (116); (2) decompose FeC₂O₄ in quartz vessel, lower section (850°C) remove nascent gases as quickly as possible, FeC₂O₄ trapped in heated portion when FeO is formed (all gas is removed) chill quickly (to prevent decomposition) (80); (3) heat Fe₂O₃ and reduced iron in sealed preevacuated quartz tubes 3 days at 900°C (80).

Thermodynamic properties:
temperature of transition: 1641°K
heat of transitions: 7.5 kcal/mol
entropy (at 298°K): 12.9 e.u.

} (79)

Flammability:

Oxide is spontaneously flammable, burns to Fe_2O_3 on exposure to air but retains spinel structure (116).

INDIUM MONOXIDE

Mol. Wt.:
130.81 (79)

Formula:
 InO

Characteristics:

White gray (79)

Solubility:

i. cold H_2O ; s. alcohol (79)

Thermodynamic properties:

standard heat of formation:
temperature of transition:
heat of transition;
entropy (at 298°K):

gas
91 kcal/mol
600°K
4.5 kcal/mol
14.5 e.u.

} (79)

Flammability:

Spontaneously flammable (50).

POTASSIUM PEROXIDE

Mol. Wt.:
110.20

Formula:
 K_2O_2

M.P.:
490°C (79)

Characteristics:
Solid - white, amorphous
deliquescent (79)

B.P.:
Decomposed (79)

Synthesis:

Oxidation of potassium in oxygen (190).

Thermodynamic properties:

standard heat of formation:
temperature of transition:
heat of transition;
entropy (at 298°K):

crystalline
-118 kcal/mol
980°K
6.8 kcal/mol
23 e.u.

} (79)

Flammability:

Ignites or explodes with H_2O (218).

l, lower sec-
tion when
at Fe_2O_3 and

MANGANESE HEPTOXIDE

Mol. Wt.:

221.87

Formula:

Mn_2O_7

M. P.:

5.9°C (79)

Characteristics:

Liquid - dark red oil (79)

d./sp. gr.:

2.396^{20}_4 (79)

B. P.:

d. 55°C (explodes 95°C) (79)

Unique conditions, reaction products:

Forms in $\text{KMnO}_4 - \text{H}_2\text{SO}_4$ mixtures (166); reacts with H_2O exothermically - initiates explosion (166).

Solubility:

v. s. cold H_2O ; d. hot H_2O ; s. H_2SO_4 (79)

Flammability:

Explodes 70°C (166).

MOLYBDENUM DIOXIDE

Mol. Wt.:

127.94

Formula:

MoO_2

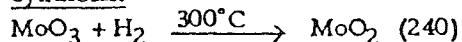
d./sp. gr.:

6.47 (79)

Characteristics:

Solid - lead gray, tetragonal or monoclinic (79)

Synthesis:



Solubility:

i. cold and hot H_2O ; ii. s. hot concentrated H_2SO_4 ; iii. alkaline solvent, HCl, HF (79)

Thermodynamic properties:

heat of formation (at 25°C);

temperature of transition:

heat of transition

entropy (at 298°K);

crystalline
-130 kcal/mol
2200°K
16 kcal/mol
14.5 e.u.

} (79)

Flammability:

Spontaneously flammable (240).

MOLYBDENUM TRIOXIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
143.94	MoO ₃	Molybdic anhydride Natural molybdate
<u>M. P.:</u>	<u>Characteristics:</u>	
795°C (79)	Solid - colorless, or white yellow rhombic	
<u>d./sp. gr.:</u>	<u>B. P.:</u>	
4.692 ²¹ (79)	(sublimes) 1155 ⁷⁶⁰ (79)	

Synthesis:

(1) roasting of molybdenite (190); (2) by ignition of the metal sulfides, lower oxides and of molybdic acids (190)

Solubility:

sl. s. H₂O; s. HNO₃ and concentrated HCl solution (190); s. acids, alkaline sulfides, NH₄OH (79)

Thermodynamic properties:

	<u>crystalline</u>	<u>aqueous solution</u>
standard heat of formation:	-180.33 kcal/mol	-188.1 kcal/mol
free energy of formation (at 25°C):	-161.95 kcal/mol	
entropy (at 25°C):	18.68 cal/°mol	
temperature of transition:	1068°K	
heat of transition:	12.54 kcal/mol	

} (79)

Flammability:

Spontaneously flammable (238)

PHOSPHORUS TRIOXIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
109.95	P ₂ O ₃	Diphosphorus trioxide
<u>M. P.:</u>	<u>Characteristics:</u>	<u>V. P.:</u>
23.8°C (79)	Solid - colorless or white powder or monoclinic deliquescent (79)	10 ^{53.0} (195)
<u>d./sp. gr.:</u>		<u>B. P.:</u>
2.135 ²¹ (79)		173.8°C (N ₂ atmosphere) (79)

Synthesis:

Precipitated by treating PCl₃ with tetramethyl ammonium sulfite in liquid SO₂

$$2\text{PCl}_3 + 3[(\text{CH}_3)_4\text{N}]_2\text{SO}_3 \rightarrow \text{P}_2\text{O}_3 + 3\text{SO}_2 + 6[(\text{CH}_3)_4\text{N}]\text{C}$$
 (132)

Solubility:

d. hot H₂O, cold H₂O to H₃PO₃; s. C₆H₆, CS₂, ether, chloroform (79)

Flammability:

Melted P₂O₃ readily ignites in air; when thrown into O₂ at 50-60°C ignites with brilliant flame (143).

SULFUR TRIOXIDE

Mol. Wt.: 80.06 Formula: SO₃ Synonyms: Sulfuric acid anhydride

M. P.:
 α 62.3°C
 β 32.5°C (79)
 γ 16.8°C

Unique conditions, reaction products:

Reacts with moisture in air to form white fog (23).

Thermodynamic properties:

	<u>gas</u>	<u>liquid</u>	}
standard heat of formation:	-94.45 kcal/mol	-104.67 kcal/mol	
free energy of formation (at 25°C):	-88.52 kcal/mol		
entropy (at 25°C)	61.24 cal/°mol		

(79)

Military and industrial uses:

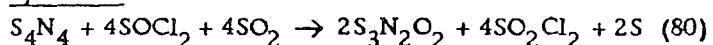
German army used SO₃ for smoke screens in World War I (23).

TRISULPHUR DINITROGEN DIOXIDE

Mol. Wt.: 156.18 Formula: S₃N₂O₂

M. P.: 100.7°C (without d.) Characteristics: Solid - pale yellow crystals (80)

Synthesis



Unique conditions, reaction products:

Turns red at 80°C, with further heating yields spontaneously flammable (300°C) yellow vapor (80).

SILICON MONOXIDE

Mol. Wt.: 44.09 Formula: SiO

M. P.: > 1702°C (79) Characteristics: Solid - white cubic (79)

d. / sp. gr.: 2.13 (79) B.P.: 1880°C (79)

Synthesis

High vacuum sublimation of silicon and quartz mixture (132).

Solubility:

i. hot and cold H₂O; s. dilute HF and HNO₃ (79)

Thermodynamic properties:

temperature of transition: 2550°K	}
heat of transition: 12 kcal/mol	
entropy (at 298°K): 6.5 e.u.	

(79)

Flammability:

Spontaneously flammable (50).

TITANIUM MONOXIDE

Mol. Wt.:

63.90

Formula:

TiO

M. P.:

1750°C (79)

Characteristics:

Solid - yellow black prism (79)

d./sp. gr.:

4.93 (79)

B. P.:

> 3000°C (79)

Synthesis:



Solubility:

s. dilute H₂SO₄; i. HNO₃ (79); s. dilute HCl [Ti⁺⁺ + H⁺ → Ti⁺⁺⁺ + $\frac{1}{2}$ H₂] (80)

Thermodynamic properties:

standard heat of formation (at 25°C): 43 kcal/mol	}
solid transition temperatures: α 1264°K; β d. 2010°K	
heat of transitions: α .82 kcal/mol	

(79)

entropy (at 298°K):	α 2.31 e.u.
---------------------	-------------

Flammability:

Spontaneously flammable (50).

URANIUM OXIDE

Mol. Wt.:

270.03

Formula:

UO₂

Synonyms:

Uranous oxide

Uranium dioxide

M. P.:

2500°C (79)

2176°C (under N₂) (80)

Characteristics:

Solid - brown, black rhombic or cubic (79)

d./sp. gr.:

10.96 (79)

Synthesis:

$\text{UO}_2\text{C}_2\text{O}_4 \cdot 3\text{H}_2\text{O} \rightarrow \text{UO}_2 + 2\text{CO}_2 + 3\text{H}_2\text{O}$ (preparation of hot concentrated solution of uranyl nitrate with oxalic acids yields a yellow powder of $\text{UO}_2\text{C}_2\text{O}_4 \cdot 3\text{H}_2\text{O}$ in a stream of hydrogen even below red heat yields a black very fine pyrophoric UO_2 powder) (80).

Solubility:

i. cold and hot H_2O ; . HNO_3 , concentrated H_2SO_4 (79)

Thermodynamic properties:

standard heat of formation:	crystalline -270 kcal/mol
free energy of formation (at 25°C):	-257 kcal/mol
temperature of transition:	3000°K
entropy (at 298°K):	18.63 e.u.

Military and industrial uses:

Used as fissionable dust carried in a gas for use in an ADFR (Armour Dust Fissionable Reactor). The gas is CO_2 , beryllium oxide the moderator, and aluminum oxide the lining material (112).

Flammability:

Spontaneously flammable black powder (80).

URANIUM HYDRIDEMol. Wt.:

273.07

Formula:

UH(OH)_2

Synthesis:

Metal uranium dissolves in excess $\text{HCl}(6\text{N})$, drying the precipitate in a vacuum yields UH(OH)_2 (102)

Unique conditions, reaction products:

With aqueous KMnO_4 yields hydrogen, with heat yields $\text{U}_3\text{O}_8 + \text{H}_2$ (102)

Flammability:

Spontaneously flammable (240).

VANADIUM SESQUIOXIDEMol. Wt.:

149.88

Formula:

V_2O_3

Synonyms:

Vanadium trioxide

M.P.:

1970°C (79)

Characteristics:

Solid - black crystal (79)

d./sp. gr.:

4.87¹⁸
4

Solubility:

s. s. cold H_2O ; s. hot H_2O , s. HNO_3 , HF, alkaline solvents (79)

Thermodynamic properties:

standard heat of formation: -290 kcal/mol
free energy of formation (at 25°C): -271 kcal/mol
temperature of transition (sol): 2240°K
entropy (at 25°C): 23.58 kcal/mol
heat of transition: 24 kcal/mol

} (79)

Flammability:

Spontaneously flammable (50).

(j) PHOSPHIDES

ALUMINUM PHOSPHIDE

Mol. Wt.:

57.96

Formula:

AlP

M. P.:

> 1700°C (231)

Characteristics:

Solid - yellow gray to dark crystals (132)

d./sp. gr.:

2.85¹⁵₄ (132)

Synthesis:

Al + P → AlP; grind aluminum powder and red phosphorus together, place in vycor reaction tube, flush with hydrogen, heat distillation flask in continuous hydrogen until the phosphorus condenses on aluminum phosphide mixture, ignite in a small hot flame and drive out excess phosphorus (80).

Unique conditions, reaction products:

Yields phosphine on reaction with H₂O (132)

CALCIUM PHOSPHIDE

Mol. Wt.:

182.19

Formula:

Ca₃P₂

Synonyms:

Photophor

M. P.:

Ca 1600°C (79)

Characteristics:

Solid - gray lumps (79)

d./sp. gr.:

2.51 (79)

Synthesis:

(1) 3C + 2P → CaP₂; (2) 3Ca₃(PO₄)₂ + 16Al → 3Ca₃P₂ + 8Al₂O₃ (cannot separate Ca₃P₂ and Al₂O₃) (80)

Solubility:

d. in cold H₂O; s. acids; i. alcohol, ether, C₆H₆ (132)

Thermodynamic properties:

heat of formation: -120.5 kcal/mol (226)

Military and industrial uses:

Used to prepare P₂H₄ (80); used in signal fires (132).

Flammability:

With water produces phosphine (PH₃) and diphosphine (PH₂); diphosphine ignites spontaneously in air (226).

CESIUM PHOSPHIDE

Mol. Wt.:
520.67

Formula:
 Cs_2P_5

Characteristics:
Reddish brown (231)

Unique conditions, reaction products:

Reacts with H_2O or moist air instantaneously to yield phosphine (231)

CUPRIC PHOSPHIDE

Mol. Wt.:
252.6

Formula:
 Cu_3P_2

M. P.:
Decomposes (195)

Characteristics:
Solid - black powder (131)

d./sp. gr.:
6.67 (195)

Synthesis:

Pass phosphine over heated cupric chloride or through solution of cupric sulphate (131).

Unique conditions, reaction products:

Yields spontaneously flammable phosphine on contact with H_2O (195).

POTASSIUM PHOSPHIDE

Mol. Wt.:
233.05

Formula:
 K_2P_5

M. P.:
About 650°C (231)

Characteristics:
Reddish brown (231)

Unique conditions, reaction products:

Phosphine produced instantaneously on reaction with H_2O or moist air (231).

LITHIUM PHOSPHIDE

Mol. Wt.:
168.73

Formula:
 Li_2P_5

M. P.:
About 650°C (231)

Characteristics:
Solid - reddish brown powder (231)

Unique conditions, reaction products:

Phosphine produced from reaction of Li_2P_5 with H_2O or moist air (231).

MAGNESIUM PHOSPHIDE

Mol. Wt.:

134.88

Formula:

Mg_3P_2

d./sp. gr.:

2.055 (79)

Characteristics:

Solid - yellow green cubic crystals (79)

Toxicity:

Heat magnesium with dehydrated organic or inorganic substances containing phosphorus, heat mixture of magnesium filings and red (or yellow) phosphorus to redness in a glass vessel (131).

Unique conditions, reaction products:

Mg_3P_2 produces phosphine and diphosphine on contact with H_2O (226).

Solubility:

d. hot and cold H_2O ; d. dilute mineral acid; sl. d. concentrated H_2SO_4 (79).

SODIUM PHOSPHIDE

Mol. Wt.:

200.83

Formula:

Na_2P_5

M. P.:

About 650°C (231)

Characteristics:

Solid - reddish brown powder (231)

Unique conditions, reaction products:

Reacts instantaneously with H_2O or moist air to yield phosphine (231).

RUBIDIUM PHOSPHIDE

Mol. Wt.:

325.81

Formula:

Rb_2P_5

Characteristics:

Reddish brown (231)

Unique conditions, reaction products:

Reacts instantaneously with H_2O or moist air to yield phosphine (231).

STANNIC PHOSPHIDE

<u>Mol. Wt.:</u> 149.66	<u>Formula:</u> SnP	<u>Synonyms:</u> Tin monophosphide Tin phosphide
<u>M. P.:</u> Decomposes (79)	<u>Characteristics:</u> Solid - silver white crystal (79)	
<u>d./sp. gr.:</u> 6.56 (79)	<u>B.P.:</u> Decomposes (79)	
<u>Unique conditions, reaction products:</u> Reacts with moisture to yield phosphine (195).		
<u>Solubility:</u> d. hot H ₂ O (79)		

(k) SILICIDES

CESIUM SILICIDE

Mol. Wt.:
161.0

Formula:
CsSi

Characteristics:

Solid - brittle brass colorless
compact mass (80)

Flammability:

Ignites explosively on contact with H₂O or dilute acid (80).

POTASSIUM SILICIDE

Mol. Wt.:
67.2

Formula:
KSi

Characteristics:

Solid - hard, poorly crystallized,
dark luster (80)

Synthesis:

Pass potassium vapor over heated silica, forms potassium silicide and silicate (131).

Flammability:

Spontaneously flammable with detonation (50); ignites spontaneously on contact with water or dilute acids (80).

LITHIUM SILICIDE

Mol. Wt.:
97.81

Formula:
Li₆Si₂

M. P.:
d. 600°C vac (79)

Characteristics:
Solid - black crystals,
hygroscopic (79)

d./sp. gr.:
About 1.12 (79)

Synthesis:

Heat silicon and lithium in vacuo for 2 or 3 hours, and finally at dull redness. Remove excess lithium with liquid NH₃ or distill off at 400°-500°C at reduced pressure (131)

Unique conditions, reaction products:

Evolves spontaneously flammable gas as result of violent reaction with water (143).

Solubility:

d. hot and cold H₂O; d. alcohol; i. NH₃, turpentine (79)

SODIUM SILICIDE

Mol. Wt.:

51.1

Formula:

NaSi

Flammability:

Spontaneously flammable as loose powder (50); spontaneously flammable and explosive with H₂O or dilute acid (80).

water or dilute

e excess lithium

(I) SULFIDES

BARIUM SULFIDE

Mol. Wt.:
169.43

Formula:
BaS

M. P.:
1200°C (79)

Characteristics:
Solid - colorless cubic
crystals (79)

d./sp. gr.:
4.25¹⁵ (79)

n_D:
2.155 (79)

Toxicity:

Acute; excess salivation, vomiting, cholic, violent diarrhea, convulsive tremors, increased blood pressure and hemorrhages in GI tract and kidneys, also muscular paralysis (190).

Synthesis:

(1) reduce sulfate with coal; (2) melt is lixiviated with hot H₂O filtered and evaporated (190)

Unique conditions, reaction products:

With damp air decomposes to carbonate with evolution of H₂S (132).

Solubility:

d. in hot and cold H₂O; i. alcohol (79)

Flammability:

Moderate fire hazard, may ignite due to air, moisture or acid fumes (27)

CARBON DISULPHIDE

Mol. Wt.:
76.14

Formula:
CS₂

Synonyms:
Dithiocarbonic anhydride
Carbon bisulphide

M. P.:
111°C (79)

Characteristics:
Liquid - colorless (79)

V.P.:
400²⁸ (195)

d./sp. gr.:
1.261²²₂₀ (79)

B.P.:
46.3°C (79)

V.d.:
2.64 (195)

n_D:
1.62950 (79)

Toxicity:

Highly toxic when ingested, inhaled or absorbed, acutely and chronically affects central nervous system; anaesthetic effect with death following respiratory failure (195); threshold limit value - 10 ppm (142).

Synthesis:

React sulphur vapors and glowing carbon in electric furnace (214).

Unique conditions, reaction products:

Decomposes to yield highly toxic fumes of sulphur oxides (195).

Ignition temperature:

flash point: -22°F (195)

autoignition temperature: 257°F (195)

Solubility:

s. alcohol; inf. s. ether (79)

Handling:

Ship in small glass or metal containers packed in fiber or protected from physical damage, isolate storage away from direct sunlight, keep cool (vapor pressure down) under H₂O and no nearby electrical installations (142).

Thermodynamic properties:

heat of fusion (at -111.99°C): 1049 ± 3 cal/mol

heat of combustion: -246.6 kcal/mol

critical temperature: 273.05°C

critical pressure: 72.868 atm

free energy of formation (at 298.1°K): 15,160 cal/mol

} (177)

Military and industrial uses:

Important solvent (dissolves sulphur, rubber, iodine and potassium) also a fumigant, disinfectant and is used in preparation of CCl₄ (214).

CALCIUM SULPHIDE

Mol. Wt.:

72.14

Formula:

CaS

Synonyms:

Natural oldhamite

M. P.:

Decomposes (79)

Characteristics:

Solid - colorless cubic (79)

d./sp. gr.:

2.5 (79)

n

$\frac{D_t}{D_e}$ (79)
2.137

Synthesis:

(1) strongly heat pulverized calcium sulphate with charcoal (190)

(2) CaCO₃ + H₂S → CaS + H₂O + CO₂ (80)

Solubility:

i. alcohol; sl. s. cold H₂O, hot H₂O (132); d. acid (79)

Flammability:

Air hazardous solid (27).

IRON SULFIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
87.91	FeS	Ferrous sulfide Nattoilite
<u>M. P.:</u>	<u>Characteristics:</u>	
1193-1199°C (79)	Solid - black brown hexagonal (79)	
<u>d./sp. gr.:</u>	<u>B.P.:</u>	
4.74 (79)	Decomposes (79)	

Synthesis:

Fe + S → FeS; seal Fe and S in quartz tube evacuated at high pressure, heat for 24 hours at 1000°C (higher and the tube bursts) reaction complete when and if S no longer collects at that end of hot tube when cooled for test purposes (80).

Solubility:

d hot H₂O; sl. d. acid; i. NH₃ (79)

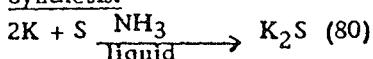
Flammability:

Spontaneously flammable (211).

POTASSIUM SULFIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
110.27	K ₂ S	Potassium sulfuret
<u>M. P.:</u>	<u>Characteristics:</u>	
471°C (195) 912°C (80)	Solid - yellow brown deliquescent cubic (79)	
<u>d./sp. gr.:</u>		
1.805 ¹⁴ (79)		

Synthesis:



Solubility:

s. cold H₂O, acid, glycerol; v. s. hot H₂O; i. ether (79)

Flammability:

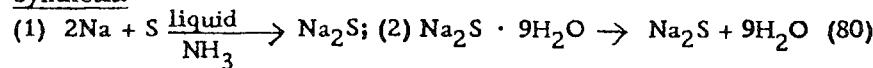
Air hazardous, moisture hazardous, may ignite spontaneously (27).

SODIUM SULFIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
78.04	Na ₂ S	Sodium monosulfide

M. P.:

1180°C (79)

CharacteristicsSolid - white deliquescent
crystals (79)d./sp. gr.:1.852¹⁴ (79)Synthesis:Solubility:s. H₂O; sl. s. alcohol; d. acid; i. ether (79)Military and industrial uses:

Powerful reducing agent (214).

Flammability:

Air hazardous substance, moisture hazardous, spontaneously flammable in air (80).

SODIUM HYDROSULPHITEMol. Wt.:

174.10

Formula:Na₂S₂O₄Synonyms:Sodium dithionite
Sodium sulfoxylateM. P.:

d. 55°C

Characteristics:Solid - white, grayish white
crystalline powder (195)Synthesis:

Dissolve Zn in solution of sodium bisulfite; Zn—NaS₂ is precipitated by milk of lime leaving the hydrosulfite in solution, add salt and hydrosulfite of crystallization is precipitated, the latter is removed by treating with hot alcohol (190).

Solubility:v. s. H₂O; sl. s. alcohol (132)Military and industrial uses:

Used as reducing agent, particularly in dying with indigo and vat dyes, bleaching soaps and straw (132)

Flammability:

Oxidizes in air, with moisture becomes damp and is liable to ignite (15).

PHOSPHORUS SESQUISULFIDEMol. Wt.:

220.09

Formula:P₄S₃Synonyms:Phosphorus tetratrisulfide
Tetraphosphorus trisulfideM. P.:

172.5°C (195)

Characteristics:

Solid - yellow rhombic (79)

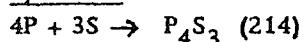
d. / sp. gr.:
2.03¹⁷ (79)

B. P.:
407°C (195)

Toxicity:

Probably toxic (195).

Synthesis:



Ignition temperature:

Autoignition temperature: 212°F (195)

Solubility:

i. cold H₂O; d. hot H₂O (79)

Handling:

Ship in glass jars and bottles, wooden cases, steel drums; protect from physical damage, store in cool ventilated place, separate from other material (142).

Military and industrial uses:

Used in matches manufacture to replace phosphorus and in synthetic organic chemistry (214).

PHOSPHORUS PENTASULFIDE

Mol. Wt.:

222.27

Formula:

P₂S₅

M. P.:

286°-290°C (79)

Characteristics:

Solid - gray yellow
deliquescent crystal (79)

d. / sp. gr.:

2.03 (79)

B. P.:

514°C (79)

V. d.:

7.67 (131)

Toxicity:

Yield poisonous H₂S if react with H₂O, threshold value of dust 1 mg/m³ (142).

Synthesis:



Ignition temperature:

287°F (142)

Autoignition temperature: 548.6°F (195)

Solubility:

i. cold H₂O; d. hot H₂O; s. alkaline solvent, .22CS₂ (79)

Handling:

Ship in glass bottles, sealed drums, protect from physical damage and moisture, separate from oxidizing materials (142).

Military and industrial uses:

Used in safety matches, ignition compounds, and for introducing sulfur into organic compounds (132).

Flammability:

Heats spontaneously, may ignite in presence of moisture (142).

THORIUM OXYSULFIDE

Mol. Wt.:

280.10

Formula:

ThOS

M. P.:

Decomposes (79)

Characteristics:

Solid - yellow crystals (79)

d./sp. gr.:

6.44 (79)

Solubility:

i. cold H₂O; s. aqua regia; sl. s. HNO₃ (79)

Flammability:

Spontaneously flammable in air (143)

(m) MISCELLANEOUS

HEXAMMINO CALCIUM

Mol. Wt.: 142.08 Formula: Ca(NH₃)₆

Flammability:

Spontaneously flammable (50).

CHLOROSULFONIC ACID

Mol. Wt.: 116.52 Formula: ClSO₂OH

M. P.: -80°C (79)

Characteristics:

Liquid - colorless, fuming, pungent odor (79)

d./sp. gr.: 1.766¹⁸ (79)

B.P.:

158°C (79)

n¹⁴
D₄
1.437 (79)

Toxicity:

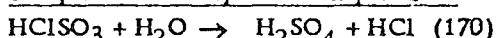
Breaks down to HCl and H₂SO₄ with moisture in lungs (142); may produce severe acid burns, irritates to eyes, lungs, and mucous membranes, on ingestion seriously irritates mouth, esophagus and stomach (195).

Synthesis

(1) pass HCl into fuming H₂SO₄ → ClSO₂OH (214)

(2) react SO₃ + HCl → ClSO₂OH (214)

Unique conditions, reaction products



Solubility:

d. to H₂SO₄ and HCl in cold H₂O (79); d. alcohol acid; i. CS₂ (79)

Handling:

Keep tightly closed, decomposes with explosive violence in H₂O (132).

Military and industrial uses:

Used in manufacture of organic sulfonic chlorides, sulfonating agent for hydroxyl compounds (214). Used by German army in World War I for smoke screens (24).

Flammability:

Fumes with air (170)

IRON (II) HYDROXIDE

Mol. Wt.:

89.86

Formula:

Fe(OH)₂

M. P.:

Decomposes (79)

Characteristics

Solid - nearly white (slightly greenish) hexagonal or white amorphous (79)

d./sp. gr.:

3.4 (79)

Synthesis

Carry on in N₂ atmosphere (absence of O₂); a centrifuged solution of Fe(OH)₂ (precipitated from pure FeCl₂) in concentrated aqueous solution of NH₃ is admitted through a filter diluted with H₂O. Heat the Fe(OH)₂ precipitate 3 hours at 80°C and allow precipitate to settle, wash in similar fashion. Solidify residue by immersion of flask in ice, salt mixture and distill off H₂O as solid slowly melts, complete drying with P₂O₅ under high vacuum (80).

Unique conditions, reaction products

When sprayed into air, burns with sparks (80).

Solubility:

cold H₂O .00015¹⁶; s. acid, NH₄Cl; i. alkaline solvent (79)

POTASSIUM CHLORATE

burns, irritat
and stomach

Mol. Wt.:

122.55

Formula:

KClO₃

M. P.:

356°C (79)

Characteristics

Solid - colorless monoclinic (79)

d./sp. gr.:

2.32 (79)

B.P.:

d. 400°C (79)

n

D:

1.409; 1.517; 1.524 (79)

Synthesis

(1) electrolysis of a hot concentrated alkaline solution of KCl (190)

(2) interaction of solutions of potassium chloride and sodium chlorate or calcium chlorate (190)

Solubility:

7.1²⁰ cold H₂O; 57¹⁰⁰ hot H₂O; 14.1¹⁰⁰ 50% alcohol; sl. s. glycol, liquid NH₃; i. acetone; s. alkaline solvent (79).

Military and industrial uses

Explosive, fireworks, matches, printing and dying cotton and wool black, source of O₂, in chemical analysis (190).

Flammability:

Spontaneously explosive (164).

DIPOTASSIUM NITROACETATE

Mol. Wt.: Formula:
181.2 $K_2(NO_2)CHCOO$

Unique conditions, reaction products:

Exploded when dry salt moistened with a little H_2O (143).

MAGNESIUM CYANIDE

Mol. Wt.: Formula:
76.31 $Mg(CN)_2$

M. P.: B.P.:
d. $300^{\circ}C$ to $MgCN_2$ (79) d. $600^{\circ}C$ (79)

Solubility:

s. cold H_2O ; d. hot H_2O (79)

Flammability:

Liable to produce fire upon exposure to air (27).

SODIUM HYDROXYLAMINE

Mol. Wt.: Formula:
53.99 $NaNH_2O$

Synthesis:

Sodium reacts incandescently with hydroxylamine in etheral solution yielding hydrogen and NH_2ONa (131).

Flammability:

Spontaneously flammable in air (143).

SODIUM HYDRAZIDE

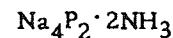
Mol. Wt.: Formula:
53.99 $NaNHNH_2$

Synthesis:

Thin slices pure sodium gradually added to ordinary free hydrazine in an atmosphere of pure dry nitrogen, a colorless precipitate is formed ($NaOH$) and liquid becomes yellow, evaporate yellow solution and $NaNHNH_2$ remained as residue (131).

Unique conditions, reaction products:

Can explode with air, alcohol, or moisture (142).



Mol. Wt.:

187.90

Unique conditions, reaction products:

Violent reaction with H_2O yields spontaneously flammable phosphine and hydrogen (156).

DIAMIDOPHOSPHORUS ACID

Mol. Wt.:

95.99

Formula:

$(\text{NH}_2)_2\text{P}(\text{O})\text{OH}$

Synthesis:

Treat phenyldichlorophosphate $\text{Cl}_2\text{POOC}_6\text{H}_5$ with NH_3 to convert it into phenyldiamidophosphate, and $(\text{NH}_2)_2\text{POOC}_6\text{H}_5$ and hydrolyze the product with a solution of potassium diamidophosphate. Heat the cold solution of this salt with CH_3COOH to form crystals of $(\text{NH}_2)_2\text{POOH}$ (131).

RUBIDIUM SILICIDE

Mol. Wt.:

113.5

Formula:

RbSi

Characteristics:

Solid - small dark crystals (80)

Unique conditions, reaction products:

Ignites explosively on contact with H_2O or dilute acids (80).

PROSILOXANE \approx OXOSILANES

Mol. Wt.:

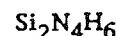
46.09

Formula:

H_2SiO

Flammability:

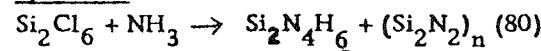
Spontaneously flammable in air (143).



Mol. Wt.:

118.18

Synthesis:



Flammability:

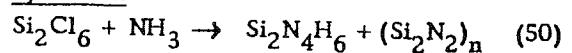
Spontaneously flammable (50).

SILICOCYN

Mol. Wt.:
 $(84.18)n$

Formulas:
 $(Si_2N_2)_n$

Synthesis:



Flammability:

Spontaneously flammable (50)

TITANIUM BORIDE

Mol. Wt.:
69.54

Formula:
 TiB_2

Synthesis:

Prepared from titanium powder and boron trichloride under argon (24).

Flammability:

Spontaneously flammable (240).

II. ORGANIC COMPOUNDS

(a) METAL

PHENYLSILVER

Mol. Wt.:

184.98

Formula:

(C₆H₅)Ag

M. P.:

d. -18°C (103)

Characteristics:

Powder - gray or brown (103)

Synthesis:

Precipitates when AgCl or AgBr is added to a cooled solution of phenylmagnesium bromide (41).

Solubility:

s. ether; i. organics (103)

Flammability:

Explosive at room temperature (41).

ETHYL DICHLOROALUMINE

Mol. Wt.:

126.96

Formula:

C₂H₅AlCl₂

Synonyms:

Ethyl aluminum dichloride

M. P.:

22°C (226)

Characteristics:

Liquid - yellow (226)

V. P.:

1280

d./sp. gr.:

1.23225

B.P.:

194°C (extrapolated) (226)

30100

69120

280168

575180

} (226)

Viscosity:

3.18 (at 23.3°C) (226)

Synthesis:

Reaction of aluminum chloride with ethyl aluminum sesquichloride (190)

Unique conditions, reaction products:

Violent reaction with H₂O (190)

Solubility:

d. H₂O, air (226)

Military and industrial uses:

Catalyst for olefin polymerization and aromatic hydrogenation (190).

Flammability:

Spontaneously flammable (226).

ALUMINUM BOROHYDRIDE MIXTURE

Mol. Wt.:
117.46

Formula:
 $\text{Al}(\text{BH}_4)_3 \cdot \text{C}_2\text{H}_6\text{O}$

Flammability:

Spontaneously ignites at room temperature after a short induction period (173).

TRIMETHYL ALUMINUM

Mol. Wt.:
72.02

Formula:
 $(\text{CH}_3)_3\text{Al}$

Synonyms:
Trimethyl alumine

M. P.:
15.4°C (226)

Characteristics:
Liquid - colorless (226)

V. P.:
8.420
68.560 } (226)
332.100 }

B. P.:
126°C (226)

Synthesis:

- (1) $2\text{Al} + 3(\text{CH}_3)_2\text{Hg} \rightarrow 2(\text{CH}_3)_3\text{Al} + 3\text{Hg}$ (109)
- (2) $\text{Al}_2\text{Mg}_3 + 6\text{CH}_3\text{Cl} \rightarrow 2(\text{CH}_3)_3\text{Al} + 3\text{MgCl}_2$ (109)

Unique conditions, reaction products:

Violent reaction with H_2O and oxidizing materials (109)

Solubility:

s. organics; d. H_2O , air (226)

Thermodynamic properties:

enthalpy of combustion: 762.1 ± 2.3 kcal/mol (714)

enthalpy of formation: (liq) -28.2 kcal/mol (714); (gas) -13.3 kcal/mol (714)

heat of combustion: 10,500 cal/g (226)

specific heat (at 33 mm): .53 (226)

Military and industrial uses:

If released in atmosphere, produces self luminous trails useful for wind measurements, wind shear, and turbulence at night (192); intermediate class of propellants (109).

Flammability:

Spontaneously flammable (226).

TRIMETHYL ALUMINUM BROMIDE

Mol. Wt.:
231.85

Formula:
 $(\text{CH}_3)_3\text{AlBr}_2$

Characteristics:
Liquid (130)

Flammability:

Pyrophoric (130)

DIETHYL ALUMINUM BROMIDE

Mol. Wt.:

164.94

Formula:

$(C_2H_5)_2AlBr$

B. P.:

383°F (126)

Characteristics:

Liquid (126)

Unique conditions, reaction products:

Ignites with air, H_2O , alcohol (126).

DIETHYL CHLOROALUMINE

Mol. Wt.:

120.56

Formula:

$(C_2H_5)_2AlCl$

Synonyms:

Diethyl aluminum chloride

M. P.:

-74°C (226)

Characteristics:

Liquid - colorless (226)

V.P.:

141

1290

65130

256170

465190

Viscosity:

.453 cp (at 23.3°C) (226)

Toxicity:

Produces deep painful burns on contact with living tissue (142).

Synthesis:

React triethyl aluminum with ethyl aluminum sesquichloride (190).

Unique conditions, reaction products:

Violent reaction with H_2O (190).

Handling:

Ship in steel cylinders, store in isolated, well ventilated, fire resistive storeroom. Protect containers from shock and damage (142).

DIETHYL ALUMINUM HYDRIDE

Mol. Wt.:

86.11

Formula:

$(C_2H_5)_2AlH$

Synonyms:

Diethyl alumine

d./sp. gr.:

.808²⁰ (103)

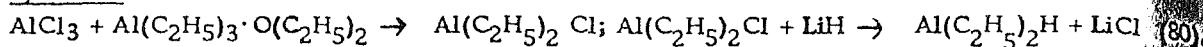
Characteristics:

Liquid - colorless (103)

V.P.:

55-56 .001-.0001 (103)

$\frac{n_{D}^{20}}{1.4702}$ (103)

Synthesis:Solubility:d. H_2O , air (103)Flammability:

Spontaneously ignites in air (145).

TRIMETHYL ALUMINE DIMETHYL ETHER

Mol. Wt.:
118.11Formula:
$$(\text{CH}_3)_5^3\text{Al}(\text{CH}_3)_2\text{O}$$
M.P.:
-30°C (226)Characteristics:
Liquid (226)B.P.:
159°C (226)Solubility:
s. organics; d. H_2O (226)Flammability:
Spontaneously flammable (226).

TRIETHYL ALUMINUM

Mol. Wt.:
114.17Formula:
$$(\text{C}_2\text{H}_5)_3\text{Al}$$
M.P.:
-46°C (226)Characteristics:
Liquid - colorless (226)V.P.:
.004⁴⁸⁻⁵⁰
.8⁶⁰
13¹⁰
110¹⁴⁰
} (226)d./sp. gr.:
.8324²⁵ (226)B.P.:
194°C (226)
207°C (extrapolated) (226)Specific heat:
.527 (at 33 mm)n_D²⁵:
$$\frac{n_{D_2}^{6.5}}{1.480} \quad (226)$$
Viscosity:
2.58 cp (at 25°C) (226)Toxicity:

High, extremely destructive to living tissue (80).

Synthesis:

$\text{Al}(\text{C}_2\text{H}_5)_2\text{Br} + \text{Na(wire)} \rightarrow \text{Al}(\text{C}_2\text{H}_5)_3 \dots$ Heat flask of $\text{Al}(\text{C}_2\text{H}_5)_2\text{Br}$ and Na wire at 105°C (with external cooling) until reaction calms, add more $\text{Al}(\text{C}_2\text{H}_5)_2\text{Br}$ and heat to 200°C for 10 hours with stirring, cool flask and add extra Na wire to ensure dehalogenation completion, resume stirring at 150°C for 1½ hours. Distill off $\text{Al}(\text{C}_2\text{H}_5)_3$ (80).

Unique conditions, reaction products:Hydrolyzes to $\text{Al}(\text{OH})_3$ immediately with moisture (80); explodes violently with H_2O (143).

Ignition temperature:

flash point: < -52.5°C (195)

autoignition temperature: < -52.5°C (195)

Solubility:

s. organics; decomposes H₂O, air (226).

Military and industrial uses:

Used in experimental tests for obtaining heat transfer parameters (73); igniter for rocket fuels (187); igniter for capsule firing flame thrower (98).

Flammability:

Spontaneously flammable (226).

DI-n-PROPYLALUMINUM HYDRIDE

Mol. Wt.:

114.04

Formula:

(C₃H₇)₂AlH

Flammability:

Ignites spontaneously in air (145).

TRIMETHYL ALUMINE-DIETHYL ETHER

Mol. Wt.:

146.21

Formula:

(CH₃)₃Al·O(C₂H₅)₂

Characteristics:

Liquid (226)

V.P.:

15⁶⁸ (226)

Solubility:

s. organic solvent; d. H₂O (226)

Flammability:

Spontaneously flammable (226).

DIISOBUTYL ALUMINUM CHLORIDE

Mol. Wt.:

176.67

Formula:

AlCl(iso-C₄H₉)₂

Synonyms:

Di-i-butylchloroalumine

M.P.:

-39.5°C (103)

Characteristics:

Liquid - colorless (103)

V.P.:

10¹⁵²

d./sp. gr.:

.9088²⁰₂₀ (103)

n_D²⁰

1.4506 (103)

5¹³⁸

108 } (103)

Viscosity:

5.11 cps (at 20°C) (103)

Unique conditions, reaction products:

Yields dense white smoke on reaction with H₂O; AlCl(isoC₄H₉)₂ + H₂O → Al(OH)₂Cl + 2isoC₄H₉ (111).

Solubility:

s. organic solvents; d. H₂O (103)

Flammability:

High spontaneous exothermic reaction (may flame) on contact with air (111).

DIISOBUTYL ALUMINUM HYDRIDE

Mol. Wt.:
142.06

Formula:
(i-C₄H₉)₂AlH

B.P.:
105°C (190)

Synthesis:

Reaction of isobutylene and hydrogen with aluminum (190).

Military and industrial uses:

Reducing agents in the manufacture of pharmaceuticals (190)

Flammability:

Pyrophoric liquid (190).

TRIPROPYLALUMINUM

Mol. Wt.:
156.25

Formula:
(n-C₃H₇)₃Al

M. P.:
-107°C (103)

Characteristics:
Liquid - colorless (103)

d./sp. gr.:
.823²⁰ (103)

B.P.:
248-252°C (103)

V.P.:
156⁵ (103)

Toxicity:

Slight (acute local) as irritant, or allergen; slight (chronic local) as allergen (195).

Unique conditions, reaction products:

Vigorous reaction with oxidizing materials, hydrolyzes to evolve flammable vapors (195); explodes violently with H₂O (143).

Solubility:

s. organic solvents; d. H₂O (103).

Flammability:

Pyrophoric (190).

TRIPROPYL ALUMINUM

Mol. Wt.: 156.25 Formula: $(i-C_3H_7)_3Al$ Synonyms: Isopropylaluminum

M. P.: -107°C (103) Characteristics: Liquid - colorless (103) V.P.: 1565 (103)

d./sp. gr.: .823²⁰ (103) B. P.: 248-252°C (103)

Solubility:
s. organic solvents; d. H₂O (103).

Flammability:
Spontaneously flammable (168).

DIETHYL 4-ETHOXY BUTYLAMINE

Mol. Wt.: 186.27 Formula: $(C_2H_5)_2Al(CH_2)_4OC_2H_5$

Characteristics: Liquid - colorless (226) V.P.: 5.5^{99.5} (226)

Solubility:
d. air; s. organic solvents (226)

Flammability:
Spontaneously flammable (226).

TRIETHYL ALUMINE DIETHYL ETHER

Mol. Wt.: 188.25 Formula: $Al(C_2H_5)_3(C_2H_5)_2O$ B.P.: 216°-218°C (226)

n^{17.4}
D: 1.4370 (226) Characteristics: Liquid - colorless (226) V.P.: 16¹¹² (226)

Flammability:
Spontaneously flammable (226)

DIETHYLDIETHYL AMINO-3-PROPYL ALUMINE

Mol. Wt.: 199.32 Formula: $(C_2H_5)_2Al(CH_2)_3N(C_2H_5)_2$

195); explodes

M. P.: -2°C (226) Characteristics: Liquid - straw (226) V. P.: 297 (226)

Solubility:

s. organic solvents; d. air (226)

Flammability:

Spontaneously flammable (226)

TRI-n-BUTYLALUMINUM

Mol. Wt.: 198. 33 Formula: $(n\text{-C}_4\text{H}_9)_3\text{Al}$

Characteristics:

Liquid - colorless (190)

Synthesis:

Exchange reaction between butene-1 and isobutyl aluminum (190)

Military and industrial uses:

Production of organotin compounds (190).

Flammability:

Pyrophoric (190)

TRI-iso-BUTYLALUMINUM

Mol. Wt.: 198. 3 Formula: $(\text{C}_4\text{H}_9)_3\text{Al}$ Synonyms: Trisobutylalumine

M. P.: 1.0 - 4.3°C (103) Characteristics: Liquid - colorless (103) V. P.: 147 (103)

d./sp. gr.: .7859²⁰ (103) n²⁰ D: 1.4494 (103) Viscosity: 2.39 cps (at 20°C) (103)

Toxicity:

High, extremely destructive to living tissue (195).

Synthesis:

React isobutylene and hydrogen with aluminum under moderate temperature and varying pressure (190).

Unique conditions, reaction products:

Reacts violently with H₂O, acids, halogens, alcohols and amines (190).

Ignition temperature:

flash point: < 4°C (195)

autoignition temperature: < 4°C (195)

Solubility:d. H₂O, air (103)Military and industrial uses:

Polyolefin catalyst; manufacture of primary alcohols and olefins; pyrophoric fuel (190).

Flammability:

Fumes violently or ignites with air (190)

TRIPHENYLALUMINUM

Mol. Wt.:

258. 30

Formula:(C₆H₅)₃AlM. P.:

230°C (103)

Characteristics:

Solid - white (103)

Solubility:d. (explosively) H₂O; s. organics (190)

1, 1, 1-TRIMETHYL TRIBROMO DIALUMENE

Mol. Wt.:

338. 81

Formula:(CH₃)₃AlAlBr₃Synonyms:

Methyl aluminum sesquibromide

M. P.:

4°C

Characteristics:

Liquid - yellow (226)

V.P.:

1560

3980

89100

185120

359140

650160

} (226)

d./sp. gr.:1.514²⁵ (226)B.P.:

166°C (extrapolated) (226)

Viscosity:

2.76 cp (at 23.3°C) (226)

Unique conditions, reaction products:Violent reaction with H₂O (190)

.03)

Solubility:s. organic solvent; d. H₂O (226)Military and industrial uses:

Catalyst for polymerization of olefins and hydrogenation of aromatics (226).

Flammability:

Spontaneously flammable (226).

METHYLALUMINUM SESQUICHLORIDE

Mol. Wt.:

205. 34

Formula:(CH₃)₃Al₂Cl₃B.P.:

143.7°C (extrapolated) (190)

F.P.:

22.8°C (190)

d./sp. gr.:1.629²⁵ (190)

Military and industrial uses:

Catalyst for polymerization of olefins and hydrogenation of aromatics (190).

Flammability:

Flames instantly in air (190).

1, 1, 2 -TRIMETHYL DIALUMENE

Mol. Wt.:

102.09

Formula:

(CH₃)₂HALAlH₂CH₃

Synonyms:

Trimethyl aluminum hydride

Unique conditions, reaction products:

Vigorous reaction with H₂O → CH₄ + H₂ + Al₂O₃ (92)

Solubility:

d. air, H₂O (226)

Flammability:

Spontaneously flammable (92)

1, 2-DIETHYL TETRAIODO DIALUMENE

Mol. Wt.:

619.72

Formula:

C₂H₅I₂AlAlI₂C₂H₅

Synonyms:

Characteristics:

Liquid (226)

V.P.:

4158-160 (226)

Solubility:

d. H₂O (226)

Flammability:

Spontaneously flammable (226)

1, 1, 2, 2-TETRAMETHYL DIALUMENE

Mol. Wt.:

116.12

Formula:

(CH₃)₂HALAlH(CH₃)₂

Characteristics:

Liquid - colorless (226)

B.P.:

Decomposes (226)

Unique conditions, reaction products:

Reacts with H₂O to yield CH₄ + H₂ + Al₂O₃ (92).

Solubility:

s. organic solvents; d. H₂O (226)

Flammability:

Spontaneously flammable (92).

PENTAMETHYL DIALUMENE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
130.14	$(\text{CH}_3)_3\text{Al}_2\text{H}(\text{CH}_3)_2$	Pentamethyl aluminum hydride
	<u>Characteristics:</u>	
	Liquid (226)	<u>B.P.:</u> d. air (226)

Unique conditions, reaction products:

Reacts with H_2O to yield $\text{CH}_4 + \text{H}_2 + \text{Al}_2\text{O}_3$ (92)

Flammability:

Spontaneously flammable (92).

1, 1, 1-TRIETHYL TRICHLORODIALUMENE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
247.52	$(\text{C}_2\text{H}_5)_3\text{AlAlCl}_3$	Ethyl aluminum sesquichloride
<u>M.P.:</u>	<u>Characteristics:</u>	<u>V.P.:</u>
-20°C (226)	Liquid - yellow (226)	14° ⁹⁰
<u>d./sp. gr.:</u>		34° ¹¹⁰
1.09225 (226)	<u>B.P.:</u> 204°C (extrapolated) (226)	76° ¹³⁰
		525° ¹⁹⁰

Viscosity:

1.91 cp (at 23.3°C) (226)

Synthesis:

Reaction of ethyl chloride and aluminum (190).

Unique conditions, reaction products:

Reacts violently with H_2O (190).

Military and industrial uses:

Catalyst for olefin polymerization and aromatic hydrogenation (190).

Flammability:

Spontaneously flammable (226).

TRIETHYL ALUMINUM ETHERATE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>B.P.:</u>
699.0 (79)	$4\text{Al}(\text{C}_2\text{H}_5)_3 \cdot 3(\text{C}_2\text{H}_5)_2\text{O}$	112° ¹⁶ (79)
	<u>Characteristics:</u> Liquid - colorless (79)	

Unique conditions, reaction products:

Explodes with moisture evolving ethane; warming evolves copious fumes of ether (195).

Solubility:

Explodes with cold H₂O (79).

Flammability:

Explodes with moisture (195).

ALUMINUM SESQUIBROMIDE ETHYLATE

Characteristics:

Liquid (125)

Unique conditions, reaction products:

Explodes with decomposition on contact with H₂O or alcohol (125).

Flammability:

Pyrophoric (125).

TRIETHYL ALUMINUM TRIETHYL BORON

Formula:

TEAB

[TEA + TEB]

15% 85%

Flammability:

Pyrophoric (186).

DIMETHYLCHLOROARSINE

Mol. Wt.:

140.44

Formula:

(CH₃)₂AsCl

Synonyms:

Dimethylarsenic monochloride

Chlorodimethyl arsine

Cacodyl chloride

M.P.:

< -45°C (79)

Characteristics:

Liquid - colorless (79)

d./sp. gr.:

1.5046¹²₄ (79)

B.P.:

109°C (79)

V.d.:

4.84 (195)

n¹²

D₄
1.5203 (79)

Synthesis:

Dissolve cacodylic acid in excess HCl and reduce with solution of hypophosphorous acid in the same reagent below 50°C. Cacodyl chloride separates as a heavy faint yellow oil which is removed in a separatory funnel, dried with CaCl₂ and distilled in a Cl₂ atmosphere (176).

Solubility:

s. alcohol; i. H₂O, ether (195).

Flammability:

Spontaneously flammable (226).

CACODYL FLUORIDE

Mol. Wt.:

123.94

Formula:

(CH₃)₂AsF

Characteristics:

Liquid - colorless (unbearable
repulsive odor) (176)

Solubility:

i. H₂O (apparently decomposed by it) (176)

Handling:

Corrosive to glass, keep in platinum container (176).

Flammability:

Spontaneously flammable (227).

CACODYL IODIDE

Mol. Wt.:

231.89

Formula:

(CH₃)₂AsI

M.P.:

-35°C (solidification
point) (176)

Characteristics:

Liquid (103); yellow oil (46)

B.P.:

154-155°C (103)

Synthesis:

(1) Aqueous solution of cacodylic acid and KI is saturated with SO₂; add 1:1 HCl from time to time. Cacodyl iodide separates as a yellow oil; (2) Methyl diiodoarsine and methyl iodide are permitted to react in alcohol concentrated aqueous caustic soda solution over night, solvent is distilled off, the residue is acidified with HCl and saturated SO₂; (3) Cacodyl chloride is gradually added to a solution of sodium iodide in dry acetone and the resulting solution permitted to stand for several hours in a CO₂ atmosphere, filter and distill off acetone from filtrate, take residue up with ether, remove the solvent from the extract by distillation and rectify residue in CO₂ atmosphere (176).

Solubility:

i. H₂O (176); s. organic solvent (103).

Flammability:

Spontaneously flammable (227).

DIMETHYL ARSINE

<u>Mol. Wt.:</u>	<u>Formula:</u>	
105.99	$(\text{CH}_3)_2\text{AsH}$	
<u>d. / sp. gr.:</u>	<u>Characteristics:</u>	<u>V.P.:</u>
1.213 ²⁹ ₂₉ (79)	Liquid - colorless (226)	1.213 ²⁰ (226) 1.210 ²⁵
<u>B.P.:</u>		
	35.6-37.0°C (226)	

Toxicity:

High (195).

Synthesis:

Add concentrated HCl slowly to a round bottom flask containing zinc dust, cacodyl oxide and alcohol. The generator is joined in series with an H_2O wash bottle, a U-tube filled with soda lime, a bulk condenser for dimethyl arsine surrounded with ice and salt and 2 wash bottles (H_2SO_4 and HNO_3). $[(\text{CH}_3)_2\text{As}]_2\text{O} + \text{H}_2 \rightarrow (\text{CH}_3)_2\text{As} \cdot \text{As}(\text{CH}_3)_2 + \text{H}_2\text{O}$; $(\text{CH}_3)_2\text{As} \cdot \text{As}(\text{CH}_3)_2 + \text{H}_2 \rightarrow 2(\text{CH}_3)_2\text{AsH}$ (176).

Solubility:

s. organic solvent (226); ∞ alcohol, ether, chloroform, carbon disulfide, acetic acid (79).

Flammability:

Spontaneously flammable (226).

CACODYL CYANIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	
131.01	$(\text{CH}_3)_2\text{AsCN}$	
<u>M. P.:</u>	<u>Characteristics:</u>	<u>B.P.:</u>
33°C (79)	Powder - lustrous colorless (79)	140°C (79)

Toxicity:

High (with slight amount in air); on inhalation causes numbness of extremities, giddiness, stupor and unconsciousness (no prolonged after effects) (176).

Synthesis:

- (1) $[(\text{CH}_3)_2\text{As}]_2\text{O} + 2\text{HCN} \xrightarrow{\text{distill}} 2(\text{CH}_3)_2\text{AsCN} + \text{H}_2\text{O}$ (contaminant of $[(\text{CH}_3)_2\text{As}]_2\text{O}$ hard to remove) (176)
- (2) $[(\text{CH}_3)_2\text{As}]_2\text{O} + \text{Hg}(\text{CN})_2 \rightarrow 2(\text{CH}_3)_2\text{AsCN} + \text{Hg}$ (176)
- (3) $[(\text{CH}_3)_2\text{As}]_2\text{O} + (\text{dry with 5 times calculated amount}) \text{ HCN} \xrightarrow[\text{sealed tube}]{\Delta} (\text{CH}_3)_2\text{AsCN}$ (use CO_2 current to remove excess HCN) (176)

Solubility:

sl. s. cold H_2O ; s. alcohol, ether (79)

Flammability:

Spontaneously flammable (227).

METHYLETHYLIODOARSINE

Mol. Wt.:

245.86

Formulas:

(CH₃)(C₂H₅)AsI

Characteristics:

Liquid - yellow oil (176)

B.P.:

65¹⁴ (176)

Synthesis:

Reflux aqueous caustic alkaline solution of ethylaliiodoarsine for a few hours with CH₃I, the solution is then neutralized, freed from alcohol, acidified with HCl and finally saturated with SO₂ (176).

Unique conditions, reaction products:

Slight decomposition on boiling (176).

Flammability:

Occasionally ignites spontaneously at ordinary temperatures (176).

ETHYL METHYL ARSINE

Mol. Wt.:

119.95

Formula:

HAs(CH₃)(C₂H₅)

B.P.:

71°C (52)

Flammability:

Ignites spontaneously in air (52).

ARSENIC TRIMETHYL

Mol. Wt.:

120.03

Formulas:

As(CH₃)₃

Synonyms:

Trimethyl arsine

M.P.:

-87.3°C (103)

Characteristics:

Liquid - colorless

V.d.:

4.14 (195)

d./sp. gr.:

1.124²² (103)

n²⁰

D₂
1.4541 (103)

Surface tension:

20.4 dynes/cm (at 20°C) (103)

Synthesis:

(1) distill tetramethyl arsonium iodide (or its double salt) with solid KOH; (2) distill ethyl magnesium iodide and arsenic tribromide in ether solution; (3) distill zinc dimethyl and arsenic trichloride; or (4) heat crude cacodyl for 2 hours at 340°C in a sealed tube filled with CO₂ (176).

Solubility:

sl. s. H₂O (103)

Thermodynamic properties:

heat of combustion: 5510.2-5576.4 cal/g
 enthalpy of combustion: 664.6 ± 1.2 kcal/mol
 enthalpy of formation: (liq) 3.5 kcal/mol; (gas) 10.6 kcal/mol
 heat of vaporization: 6600 cal/mol (103)

}

(114)

Flammability:

Flames spontaneously in air (143)

DIETHYL ARSINE

Mol. Wt.:

134.05

Formula:

$(C_2H_5)_2AsH$

d./sp. gr.:

1.338^{24}_4 (226)

Characteristics:

Liquid - colorless (226)

B.P.:

105 96.5 - 97 (226)

n_{D}^{25}
 $D = 1.4709$ (226)

Solubility:

s. H_2O (226)

Flammability:

Spontaneously flammable (226)

DIMETHYL ALLYL ARSINE

Mol. Wt.:

87.93

Formula:

$CH_2=CH-CH_2-As-(CH_3)_2$

Characteristics:

Liquid - pale yellow (176).

B.P.:

108-110°C (52)

Synthesis:

From dimethyl arsine and allyl iodide (176).

Unique conditions, reaction products:

With bromine in ether solution yields the corresponding arsine dibromide (176).

Flammability:

Ignites in air and on filter paper (52)

ARSENIC TRIETHYL

Mol. Wt.:

162.11

Formula:

$As(C_2H_5)_3$

Synonyms:

Triethyl arsine

<u>d./sp. gr.:</u>	<u>Characteristics</u>	<u>V.P.:</u>
1. 150 ₄ ²⁰ (103)	Liquid - colorless (103)	15 ^{36.5} - 37 (103)
<u>B.P.:</u>	<u>n_D²⁰</u>	<u>V.d.:</u>
140 ₇₃₆ (sl. d.) (103)	D ₄ 1. 4751 (103)	5.59 (195)
	<u>n_D²⁵</u>	<u>Surface tension:</u>
	D ₄ 1. 4670 (103)	25.2 dynes/cm (at 20°C) (103)

Toxicity:

High (195)

Synthesis:

(1) react arsenic trichloride with zinc diethyl; (2) distill tetraethylarsenium iodide (or its double salt) and $(C_2H_5)_4AsI \cdot AsI_3$ with solid caustic potash (176).

Solubility:

i. H_2O ; ∞ alcohol ether (103)

Thermodynamic properties:

heat of combustion: 7129 ± 13 cal/g

enthalpy of combustion: 1158.2 ± 2.0 kcal/mol

enthalpy of formation: (gas) 13.4 kcal/mol; (liq) 3.1 kcal/mol

}

(114)

Flammability:

Spontaneously flammable in air (143).

CACODYL

Mol. Wt.:

209.94

Formula:

$(CH_3)_2AsAs(CH_3)_2$

Synonyms:

Tetramethyl diarsine

Diarsenic tetramethyl

Dimethylarsine

Dicacodyl

Tetramethyldiarsyl

M.P.:

-5°C (79)

Characteristics:

Liquid - oily yellow (79)

d./sp. gr.:

1. 44715 (79)

B.P.:

163₇₆₀ (79)

Toxicity:

Very high (195).

Synthesis:

(1) heat cacodyl chloride with zinc at 90-100°C in CO_2 atmosphere

(2) reduce cacodylic acid and HCl solution with hypophosphorous acid

(3) reduce cacodylic acid and $3NH_2SO_4$ solution by electrolytic means

}

(176)

Unique conditions, reaction properties:

If heated to decomposition emits arsenic fumes (195); flames spontaneously in chlorine (176)

Ignition temperature:

Flash point > 100°F (27)

Solubility:

s. alcohol, ether (69).

Flammability:

Spontaneously flammable in dry air (50)

CACODYL DIOXIDE

Formula:

$[(CH_3)_2As]_2O_2$

Characteristics:

Liquid (195)

Handling:

Decomposes with heat to yield arsenic fumes (195).

Flammability:

Spontaneously flammable (195).

CACODYL SULFIDE

Mol. Wt.:

242.05

Formula:

$[(CH_3)_2As]_2S$

Synonyms:

Tetramethyl diarsinthiane

Bisdimethylarsine sulfide

Dicacodyl sulfide

M. P.:

< -40°C (195)

Characteristics:

Liquid - oily (79)

B. P.:

211°C (79)

Synthesis:

(1) Pass H₂S through a concentrated alcoholic solution of cacodylic acid; (2) Distill cacodyl chloride with boron hydrosulfide; (3) Heat 2 moles dimethyl arsine with less than 1 mole sulfur in a sealed tube and allow to stand 2-3 days (176).

Unique conditions, reaction products:

If heated to decomposition it emits toxic arsenic and sulfur fumes (195).

Solubility:

sl. s. H₂O; s. alcohol, ether (79)

Flammability:

Ignites spontaneously in air (195).

TETRAMETHYL DIARSINE

Mol. Wt.:

266.07

Formula:

$(C_2H_5)_2As_2(C_2H_5)_2$

<u>d./sp. gr.:</u>	<u>Characteristics:</u>	<u>B.P.:</u>
1.2 ^{23.7} ₄ (226)	Liquid (226)	185°-190°C (226)
	n_{D}^{25} 1.4709 (226)	

Synthesis:

Mix sodium arsenide with four to five times its weight of quartz sand and reflux with ethyl iodide in an atmosphere of CO₂, let the reaction finish and cool; extract with ether in CO₂ atmosphere and mix extract with absolute alcohol (176).

Solubility:

i. H₂O; s. alcohol, ether (226)

Flammability:

Spontaneously flammable (226).

PHENYL CACODYL

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
458	(C ₆ H ₅) ₂ As(C ₆ H ₅) ₂	Tetraphenyl diarsine
<u>M. P.:</u>	<u>Characteristics:</u>	
200 (103)	Crystal (103)	

Synthesis:

(1) Reflux alcoholic diphenylarsineoxide with an excess of phosphorous acid; (2) Heat alcoholic diphenylarsenic acid with a large excess of some reducing agent in a sealed tube for 10 hours at 100°C; (3) Stir diphenylchloroarsine with phosphorous acid at 100°C (176).

Solubility:

s. ethanol; sl. s. ethanone (103)

Flammability:

Spontaneously flammable (50).

ETHYL BORON DICHLORIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>B.P.:</u>
110.71	C ₂ H ₅ BCl ₂	1 ¹⁰⁰ (207)

Synthesis:

Heat triethylborine and boron trichloride for 4 hours at 200°C (204);
 $(C_2H_5)_3B + BC_3 \rightarrow C_2H_5BCl_2 + (C_2H_5)_2BCl$ (206-207)

Military and industrial uses:

Preparation of borazoles (206-207)

Flammability:

Spontaneously flammable (204).

TRIMETHYL BORON

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
55.92	B(CH ₃) ₃	Trimethyl borine Boron trimethyl Boron methyl
<u>M. P.:</u>	<u>Characteristics:</u>	
-153° ^{161.5} (226)	Gas - colorless (79)	
<u>d./sp. gr.:</u>	<u>B.P.:</u>	<u>V.P.:</u>
.63-100 (226) 1.9108	-20°C (226)	80-50 (226) 31-80

Synthesis:

A grignard reaction of (Mg + n-butyl ether + CH₃Br) takes 6 hours for completion in an oxygen free nitrogen atmosphere, bubble nitrogen through the subsequent reaction, add BF₃ dropwise at -78°C, warm to 70°C, in 2 hours the product condenses in cold traps. Purify product by high vacuum distill at 78°C. Trap in receiver at -124°C or substitute ethyl ether for n-butyl ether and add BF₃ in form of diethyl etherate or bubble into grignard solution as a gas. Keep H₂SO₄ present between the condense and the traps to absorb any ether present in product gas (80).

Solubility:

s. organic solvent; d. air (226)

Thermodynamic properties:

heat of vaporization: 5.7 kcal/mol (226)

heat of combustion: 23,000 Btu/lb (226)

Flammability:

Spontaneously flammable (226).

BUTYL BORON DICHLORIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>B.P.:</u>
138.84	C ₄ H ₉ BCl ₂	31 ¹⁰ (204)
	<u>Characteristics:</u>	
	Liquid (103)	88 (103)

Synthesis:

Heat 14 moles of tributylborine for 20 hours at 200°C with .31 moles of borine trichloride (204) (n-C₄H₉)₃B + 2BCl₃ → 3C₄H₉BCl₂ (208).

Solubility:

s. organic solvent; d. H₂O (103)

Flammability:

Spontaneously flammable (204).

BUTYL BORON DIFLUORIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>B.P.:</u>
105.84	C ₄ H ₉ BF ₂	35° ⁷⁶⁰ (204)

Synthesis:

Heat tributylborine and boron trifluoride for 24 hours at 200°C and 20 hours at 205°C (204).

Unique conditions, reaction products:

Not pyrophoric but fumes strongly in air (204).

DIETHYL BORON CHLORIDE

<u>Mol. Wt.:</u>	<u>Formulas:</u>	<u>Synonyms:</u>
104.40	(C ₂ H ₅) ₂ BCl	Diethylchloroborine
<u>M.P.:</u> -84.6°C (103)	<u>Characteristics:</u> Liquid (103)	<u>B.P.:</u> 25100 (103)

Synthesis:

Heat triethylborine and boron trichloride four hours at 200°C (204);
 $2(C_2H_5)_3B + BCl_3 \rightarrow C_2H_5BCl_2 + (C_2H_5)_2BCl$ (207)

Solubility:

s. organic solvent; d. H₂O (103)

Thermodynamic properties:

heat of vaporization: 7.9 kcal/mol (103)

Flammability:

Spontaneously flammable (204).

DIISOPROPYL CHLOROBORINE

<u>Mol. Wt.:</u>	<u>Formula:</u>
132.45	(C ₃ H ₇) ₂ BCl [BC ₆ H ₁₄ Cl]
<u>M.P.:</u> < 125°C (226)	<u>Characteristics:</u> Liquid - colorless (226)
<u>d./sp. gr.:</u> .848 ²⁰ (226)	<u>B.P.:</u> 127°C (226)

Solubility:

s. organic solvents (226)

Flammability:

Spontaneously flammable (226).

TRIETHYL BORINE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
98.00	$B(C_2H_5)_3$	Boron triethyl Triethyl boron Boron ethyl
<u>M. P.:</u>	<u>Characteristics:</u>	
-93°C (226)	Liquid - colorless (226)	
<u>d. /sp. gr.:</u>	<u>n_D²⁰:</u>	<u>V. P.:</u>
.696 ²⁰ (226)	1.4485 (226)	12.50 (226)
<u>B. P.:</u>		<u>Viscosity:</u>
95°C (226)		.30 (at 77°F) (237)

Synthesis:

Add an n-butyl ether solution of BF_3 dropwise to a solution of C_2H_5MgBr in n-butyl ether, after the reaction is completed the product is distilled at 95°C under N_2 (80).

Unique conditions, reaction products:

Emits toxic fumes when heated to decomposition (195).

Solubility:

s. organic solvents; d. air (226).

Thermodynamic properties:

heat of combustion: 21,900 Btu/lb (226).

Military and industrial uses:

Igniter for rocket fuels (186); igniter for capsule flame thrower (99).

Flammability:

Ignites spontaneously at partial pressures below 1 mm at 0°C (226); spontaneously flammable in air (237).

DIBUTYL BORON CHLORIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
160.5°C	$(C_4H_9)_2BCl$	Dibutyl chloroborine
<u>Characteristics:</u>	<u>B. P.:</u>	
Liquid - colorless (103)	54 ¹⁰ (210)	

Synthesis:

Redistribution of 2 moles of tributylborine with one mole of boron trichloride (210).

Solubility:

s. organic solvent; d. H_2O (103)

Thermodynamic properties:

heat of formation (gas): -98.1 ± 2 kcal/mol (714)

heat of formation (liq): -110 ± 1.6 kcal/mol (714)

Military and industrial uses:

Used in preparation of several borinates (210).

Flammability:

Spontaneously flammable (210).

TRIPROPYL BORON

Mol. Wt.:

140.1

Formula:

(C₃H₇)₃B

M. P.:

-52.5°C (103)

Characteristics:

Liquid - colorless (195)

B.P.:

15720 (195)

d./sp. gr.:

.725 (195)

n^{22.8}

D_t (79)

1.4135

Solubility:

i. H₂O; s. ether (195)

Flammability:

Spontaneously flammable (247),

PHENYL CYCLOTETRAMETHYLENE BORINE

Mol. Wt.:

144.02

Formula:

C₆H₅B(CH₂)₄

Characteristics:

Liquid - colorless (226)

V.P.:

1185-87 (226)

Solubility:

s. organic solvent; d. air (226)

Flammability:

Spontaneously flammable (226).

TRI-n-BUTYLBORANE

Mol. Wt.:

182.16

Formula:

(C₄H₉)₃B

M. P.:

-34°C (190)

B.P.:

170222 (190)

V.P.:

-120 (190)

d./sp. gr.:

.74725 (190)

n²²

D_t (190)

1.4285

Ignition temperature:

flash point: -32°F (190)

Solubility:

i. H₂O; s. most organic solvents (190)

Handling:

Store, transfer or use in an inert atmosphere (dry nitrogen or argon) store in dry ventilated room at room temperature (190)

Thermodynamic properties:

heat of vaporization (at 25°C): 2110 ± 10 kcal/mol

heat of formation (at 25°C) (liq): -94 kcal/mol

heat of formation (at 25°C) (gas): -81 kcal/mol

} (114)

Flammability:

Rapid oxidation in air; will ignite spontaneously if spread over a large area (101).

(METHYL SILY) AMINO DIBORANE

Mol. Wt.:

86.81

Formula:

(B₂H₅)N(CH₃)(SiH₃)

B.P.:

51°C (226)

M. P.:

-39.0°C (226)

Characteristics:

Liquid - colorless (226)

V.P.:

82° (226)

Solubility:

s. organic solvents; d. H₂O, air (226)

Thermodynamic properties:

heat of vaporization (at 60°C): 7716 cal/mol (226)

Flammability:

Spontaneously flammable (226).

DIMETHYLAMINOCHLORODIBORANE

Mol. Wt.:

105.11

Formula:

(CH₃)₂NB₂H₄Cl

Characteristics:

Liquid (103)

$\frac{n^0}{D}:$ 6.5 (103)

$\frac{n^{20}}{D}:$ 18 (103)

Synthesis:

n-methyl derivative of B₂H₇N (29)

Solubility:

s. organic solvent; d. H₂O, air (103)

Flammability:

Spontaneously flammable (29)

1, 1, 2-TRIMETHYL DIBORANE

Mol. Wt.:

69.75

Formula:

B₂H₃(CH₃)₃

M.P.:

-123°C (79)

[(CH₃)₂BH₂(CH₃)]

B.P.:

45.5°C (79)

Characteristics:

Liquid - colorless (79)

Solubility:

s. organic solvent; d. H₂O, air (103)

Thermodynamic properties:

heat of combustion: 24,000 Btu/lb (202)

heat of vaporization: 7.0 kcal/mol (103)

Flammability:

Spontaneously flammable (202).

TETRAMETHYL DIBORANE

Formula:

H(CH₃)₂BB(CH₃)₂H (See pages 181-182)

TRIETHYL DIBORANE

Mol. Wt.:

111.82

Formula:

(C₂H₅)₃B₂H₃

Characteristics:

Liquid - colorless (226)

V.P.:

40 (226)

Solubility:

s. organic solvents (226)

Flammability:

Spontaneously flammable (226)

N-METHYL N,N-BIS(DIETHYLBORINIC)IMIDE

Mol. Wt.:

166.92

Formula:

((C₂H₅)₂B)₂NCH₃

Characteristics:

Liquid (209)

B.P.:

46^{12.6} (209)

Synthesis:

Diethylboron chloride reacts with 1 mole monomethylamine using triethylamine in excess as an HCl acceptor (205); $(C_2H_5)_2BCl + CH_3NH_2 + (C_2H_5)_3N \rightarrow ((C_2H_5)_2B)_2NCH_3 + (C_2H_5)_3NHCl$ (209)

Flammability:

Spontaneously flammable (205).

TETRABUTYL DIBORINYL OXYETHANE

Mol. Wt.:

310.14

Formula:

$(C_4H_9)_2BOCH_2CH_2OB(C_4H_9)_2$

d./sp. gr.:

.8266²⁵ (226)

Characteristics:

Liquid - colorless (226)

V.P.:

2144

10168-169
1133-134

} (226)

n^{27}
D: (226)
1.4343

n^{25}
D: (226)
1.4323

Flammability:

Spontaneously flammable (226).

TRICHLOROTRIMETHYLBORAZOLE

Mol. Wt.:

225.96

Formula:

$B_3N_3Cl_3(CH_3)_3$

Synonyms:

NN'N"-Trimethyltrichlorocyl-
triborazine

M. P.:

150°C (210)

Characteristics:

Crystal - colorless (210)

Synthesis:

Reaction of methylamine-boron trichloride complex with triethylamine in toluene gives about 50% trichlorotrimethylborazole (210).

Unique conditions, reaction products:

Reacts violently with water (not pyrophoric) (210).

HEF-2 (ALKYLATED PENTABORANE)

Mol. Wt.:

91.12

Formula:

$C_2H_5B_5H_8$

Synonyms:

Ethyl pentaborane

Toxicity:

Highly toxic on inhalation, ingestion, and skin or eye contact (147).

Unique conditions, reaction products:

Reacts slowly with H₂O to yield hydrogen; reacts violently with alcohol (149).

Solubility:

i. H₂O; s. hydrocarbon fuels, halogenation hydrocarbon fuels (may form extremely shock sensitive mixtures) (149)

Flammability:

Spontaneously flammable (149).

DIMETHYL BERYLLIUM

Mol. Wt.:

39.09

Formula:

(CH₃)₂Be

B.P.:

d. 190°C (226)

M. P.:

Sublimes 200°C (226)

Characteristics:

Needles - white (226)

V.P.:

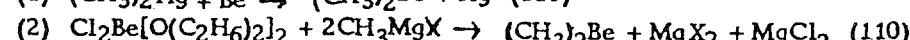
1108 (226)

30.5158.6

Toxicity:

High (195)

Synthesis:



Unique conditions, reaction products:

Evolves dense white fumes in moist air (110)

Solubility:

s. hot ether (226)

Thermodynamic properties:

heat of sublimation: 22 kcal/mol (226)

Military and industrial uses:

Potential high energy propellant (110)

Flammability:

Spontaneously flammable in moist air (110).

DIETHYL BERYLLIUM

Mol. Wt.:

67.14

Formula:

Be(C₂H₅)₂

B.P.:

(extrapolated) 194°C (226)

M. P.:

-13°C to -11°C (226)

Characteristics:

Liquid - colorless (226)

V.P.:

d. 493-95 (226)

Solubility:

s. organic solvents (226)

Flammability:

Spontaneously flammable (27).

DIISOPROPYLBERYLLIUM

Mol. Wt.:

95.19

Formula:

Be(C₃H₇)₂

M. P.:

-9.5°C (103)

Characteristics:

Liquid - colorless (103)

B.P.:

d. 60°C;

(extrapolated) 280°C (103)

Unique conditions, reaction products:

Fumes on exposure to air but does not catch fire, explosive reaction with H₂O (42).

Solubility:

d. air, H₂O; s. organic solvents (103).

BISMUTH ETHYL CHLORIDE

Mol. Wt.:

274.5

Formula:

BiHC₂H₅Cl

Characteristics:

Powder (195)

Flammability:

Spontaneously flammable (195).

TRIMETHYL BISMUTH

Mol. Wt.:

254.10

Formulas:

Bi(CH₃)₃

Synonyms:

Trimethylbismuthine

d./sp. gr.:

2.300¹⁸ (195)

Characteristics:

Liquid - colorless (195)

B.P.:

110°C (195)

Toxicity:

(1) high (causes narcosis and CNS depression); prolonged exposure causes encephalopathy similar to organic lead compounds (195).

Unique conditions, reaction products:

Reactions of methyl magnesium iodide and bismuth chloride (38).

Thermodynamic properties:

heat of formation: (liq) +37.5 kcal/mol

heat of formations (gas) +45.8 kcal/mol

heat of vaporizations: 696.0 ± 1.7 kcal/mol

} (114)

Flammability:

Spontaneously flammable (39).

DIETHYL BISMUTH CHLORIDE

Mol. Wt.:

302.47

Formula:

$(C_2H_5)_2BiCl$

Synthesis:

From ethylation of bismuth chloride with tetraethyl lead (39).

Flammability:

Spontaneously flammable (39).

C (103)

TRIVINYL BISMUTH

Mol. Wt.:

290.14

Formulas:

$(CH_3CH)_3Bi$

B.P.:

158.1⁷²² (242)

Solubility:

s. organic solvents; i. H₂O (242)

Flammability:

Spontaneously flammable (242).

TRIETHYL BISMUTH

Mol. Wt.:

254.09

Formulas:

$Bi(C_2H_5)_3$

M.P.:

107°C (52)

Characteristics:

Liquid (79)

V.P.:

(experimental) 79¹⁰⁷ (103)

d./sp. gr.:

2.300¹⁸ (79)

B.P.:

110°C (79)

Solubility:

s. alcohol, ether; i. H₂O (79)

milar to

The thermodynamic properties:

heat of vaporization: 1185.8 ± 2.1 kcal/mol

heat of formation: (liq) 40.1 kcal/mol

heat of formation: (gas) 51.1 kcal/mol

}

(114)

Flammability:

Spontaneously flammable (52).

DIMETHYL CADMIUM

<u>Mol. Wt.:</u>	<u>Formula:</u>	
142.5	$(\text{CH}_3)_2\text{Cd}$	
<u>M. P.:</u>	<u>Characteristics:</u>	<u>B.P.:</u>
-2.5°C (226)	Liquid - colorless (226)	105.5°C (226)
<u>d./sp. gr.:</u>	<u>Atomic refraction:</u>	
1.9846 ^{17.9} (226)	$\frac{n^{18}}{D^{\circ}}$ (226)	12.61 (226)
1.5849		

Solubility:

d. H_2O ; s. organic solvents (226)

Thermodynamic properties:

heat of combustion: $3330 \pm 20 \text{ cal/g}$ (114)

heat of fusion: 9153 cal/mol at 18°C (226)

enthalpy of combustion: $475.7 \pm 2.8 \text{ kcal/mol}$ (114)

enthalpy of formation: (liq) 18.9 kcal/mol; (gas) 27.8 kcal/mol (114)

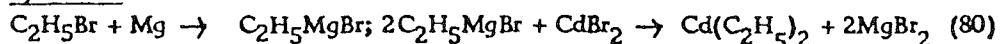
Flammability:

Spontaneously flammable (226).

DIETHYL CADMIUM

<u>Mol. Wt.:</u>	<u>Formula:</u>	
170.5	$(\text{C}_2\text{H}_5)_2\text{Cd}$	
<u>M. P.:</u>	<u>Characteristics:</u>	<u>V.P.:</u>
-21°C (79)	Liquid - oil (79)	19.564 (103)
<u>d./sp. gr.:</u>	<u>B.P.:</u>	<u>n¹⁸</u>
1.6562 (79)	64°C (79)	D° (103)
		1.5680

Synthesis:



Unique conditions, reaction products:

Fumes explosively in air, white and then brown clouds appear with detonation (80).

Solubility:

d. H_2O (79); s. organic solvents (103)

Thermodynamic properties:

heat of combustion: $4681 \pm 5 \text{ cal/g}$

enthalpy of combustion: $800.0 \pm .8 \text{ kcal/mol}$

enthalpy of formation: (liq) 21.6; (gas) 31.0 kcal/mol

}

(114)

Military and industrial uses:

TEL production; synthesis of ketones from acid chlorides (190).

COBALTOUS RESINATE

Mol. Wt.:
1368.81 (195)

Formula:
 $\text{Co}(\text{C}_{44}\text{H}_{62}\text{O}_4)_2$

Synonyms:
Cobalt abietate

Characteristics:
powder - red brown (195)

Synthesis:

- (1) (crude) fuse resin with a cobaltous compound
- (2) mix sodium resinate and a cobalt salt in an aqueous solution (214)

Solubility:

i. H_2O (195)

Military and industrial uses:

Drier in protective coatings (214)

Flammability:

Spontaneously flammable (195).

METHYL COPPER

Mol. Wt.:
78.58

Formula:
 CH_3Cu

Characteristics:
Gas (226)

Synthesis:

Mix methyl lithium and cuprous iodide at -15°C , yellow solid separates which decomposes in boiling ether to yield a formation of metallic copper, methane, and ethane appearing to be methyl copper (40).

Solubility:

s. ether (226)

Flammability:

Explodes violently when allowed to dry in air (40).

TRIMETHYL GALLIUM

Mol. Wt.:
114.82

Formula:
 $\text{Ga}(\text{CH}_3)_3$

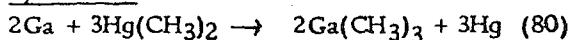
B.P.:
 55.7°C (226)

M.P.:
 -15.8°C (226)

Characteristics:
Liquid - colorless (226)

V.P.:
 64.50 (226)

d./sp. gr.:
 $1.151 \pm .00415$ (120)

Synthesis:Solubility:

d. H_2O ; s. ether, ammonia (226).

Thermodynamic properties:

heat of formation: 17.6 kcal/mol (120)

mean heat of combustion $(\text{Ga}(\text{CH}_3)_3 \text{ (liq)} + \text{CO}_2 \rightarrow \text{Ga}_2\text{O}_3 \text{ (crystal)} + 3\text{CO}_2 + 4\frac{1}{2}\text{H}_2\text{O} \text{ (liq)})$:
6089.3 cal/g (with mean deviation of .24% or 701.0 kcal/mol at 25°C and constant pressure, statistical uncertainty is ± 1.7 kcal/mol) (120).

Flammability:

Spontaneously flammable (226).

TRIETHYL GALLIUMMol. Wt.:

156.91

Formula:

$\text{Ga}(\text{C}_2\text{H}_5)_3$

M. P.:

-82.3°C (52)

Characteristics:

Liquid - colorless (79)

d./sp. gr.:

1.0576³⁰ (79)

B.P.:

142.6°C (52)

Solubility:

d. cold H_2O ; s. ether (79)

Flammability:

Ignites in air with purple flame and brown smoke (52).

TETRAMETHYL DIGALLINEMol. Wt.:

199.58

Formula:

$(\text{CH}_3)_2\text{GaGa}(\text{CH}_3)_2$

B.P.:

172°C (extrapolated) (226)

Characteristics:

Liquid - colorless (226)

V.P.:

.50

500130 (with d.)⁽²²⁶⁾

Flammability:

Spontaneously flammable (226).

TRIMETHYL INDIUMMol. Wt.:

159.93

Formula:

$\text{In}(\text{CH}_3)_3$

Synonyms:

Indium methylate

M. P.:
88.4°C (226)

Characteristics
Crystal (226)

d./sp. gr.:
1.568¹⁰ (226)

B. P.:
135.8°C (226)

V. P.:
7.2³⁰
7270 (226)

Solubility:

s. organic polymers; d. H₂O, air (226)

TRIETHYL INDIUM

Mol. Wt.:
202.40

Formula:
(C₂H₅)₃In

M. P.:
-32°C (226)

Characteristics
Liquid - colorless (226)

d./sp. gr.:
1.538²⁰ (226)

B. P.:
144°C (226)

Solubility:

d. H₂O, air; s. organic solvents (226)

Flammability:
Spontaneously flammable in air (226).

TRIPROPYL INDIUM

Mol. Wt.:
244.10

Formula:
(C₃H₇)₃In

M. P.:
-51°C (226)

Characteristics
Liquid - colorless (226)

d./sp. gr.:
1.501²⁰ (226)

B. P.:
178°C (226)

Solubility:

s. organic solvents; d. H₂O, air (226)

Flammability:
Spontaneously flammable (226).

POTASSIUM NITROMETHANE

Mol. Wt.:
99.20

Formula:
KCH₂NO₂

Unique conditions, reaction products

Na or K salts of nitromethane exploded when dry salt was moistened with a little H₂O (143).

TETRAACETENYL NICKEL TETRAPOTASSIUM

Mol. Wt.:
276.13 (103)

Formula:
K₄[Ni(C≡CH)₄]

Characteristics:
Red (103)

Flammability:

Spontaneously flammable (103).

METHYL LITHIUM

Mol. Wt.:
21.96

Formula:
CH₃Li

Characteristics:
Solid (226)

Synthesis:

React lithium metal and methyl chloride in anhydrous ether or dimethyl mercury with ethyl lithium (pure product) [2LiC₂H₅ + Hg(CH₃)₂ → 2LiCH₃ + Hg(C₂H₅)₂] (184).

Flammability:

Spontaneously flammable (226).

ETHYL LITHIUM

Mol. Wt.:
36.00

Formula:
LiC₂H₅

Synonyms:
Lithium ethyl

M.P.:
95°C (103)

Characteristics:
Tablets - colorless (103)

V.P.:
.00045⁷⁰ (103)

B.P.:
sublimes (103)

Solubility:
s. organic solvents (103)

Flammability:
Spontaneously flammable (50).

N-PROPYL LITHIUM

(143).

Mol. Wt.:

50.04

Formula:

LiC_3H_7

Characteristics:

Liquid - colorless (103)

V.P.:

.000550 (103)

Flammability:

Spontaneously flammable (50).

BUTYL LITHIUM

Mol. Wt.:

64.05

Formula:

LiC_4H_9

M.P.:

sublimes at 80°-100°C
(in vacuo)

Characteristics:

Liquid - colorless (103)

V.P.:

.0004560 (103)
.00170 (103)

d./sp. gr.:

.68 - .70 (190)

B.P.:

150°C (79)

Toxicity:

Caustic; burns with skin contact (81).

Synthesis:

Reaction of finely dispersed lithium metal with butyl chloride (138).

Solubility:

s. organic solution (103)

Thermodynamic properties:

heat of sublimation: 33 kcal/mol (103)

dipole moment: .970 (103)

Military and industrial uses:

Used as stereo-regulator for polymerizations to complex organic compounds; as a catalyst for polyisoprene rubber; and as a metalating agent (138).

Flammability:

Can spontaneously ignite in air if: 20% or more LiC_4H_9 and relative humidity over 70%; concentrations above 25% generally pyrophoric under any range of humidity (138).

LITHIUM TETRAMETHYL BORATE

Mol. Wt.:

30.77

Formula:

$\text{Li}(\text{CH}_3)_4\text{B}$

Synthesis:

React methyl lithium and trimethylborane in ethyl ether (48)

Unique conditions, reaction products:

Stable in very dry air (48).

Solubility:

s. ether (48).

Flammability:

May ignite spontaneously in moist air (48).

PHENYL LITHIUM

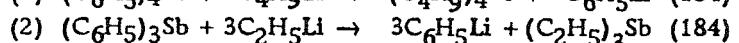
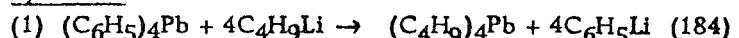
Mol. Wt.:

84.00

Formula:

C₆H₅Li

Synthesis:



Flammability:

Spontaneously flammable (50).

METHYLENE DILITHIUM

Mol. Wt.:

27.91

Formula:

LiCH₂Li

Characteristics:

Solid - brown (226)

Solubility:

d. H₂O, air; i. alcohol (226)

Flammability:

Spontaneously flammable in air (226).

METHYLENE MAGNESIUM

Mol. Wt.:

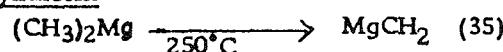
38.35

Formula:

MgCH₂

Characteristics:

Solid - rust colored,
amorphous (226)

Synthesis:Solubility:

d. H_2O , air; i. organic solvents (226)

Flammability:

Spontaneously flammable (34).

DIMETHYL MAGNESIUMMol. Wt.:

54.50

Formula:

$Mg(CH_3)_2$

M. P.:

d. $200^\circ C$ (226)

Characteristics:

Solid (226)

V.P.:

.2190 (226)

Solubility:

s. ether (226)

Flammability:

Spontaneously flammable (34)

MAGNESIUM DIETHYLMol. Wt.:

82.44

Formula:

$Mg(C_2H_5)_2$

M. P.:

$0^\circ C$ (195)

Characteristics:

Liquid (room temperature)
(195)

B.P.:

d. $176^\circ C$ (103)

Synthesis:

Precipitated by action of Mg on $Hg(C_2H_5)_2$ in ether (132).

Unique conditions, reaction products:

Violent reaction with H_2O , steam or oxidizing materials (195); spontaneously flammable in CO_2 (143).

Solubility:

s. ether (132).

Flammability:

Spontaneously flammable in air (195).

DIBUTYL MAGNESIUMMol. Wt.:

138.72

Formula:

$(C_4H_9)_2Mg$

M. P.:
d. 200°C (226)

Characteristics:
Crystal (226)

Solubility:
s. ether (226)

Flammability:
Spontaneously flammable (226).

MAGNESIUM DIPHENYL

Mol. Wt.:
178.5

Formula:
 $Mg(C_6H_5)_2$

M. P.:
d. 280°C (132)

Characteristics:
Crystals - feathery

Synthesis:
Action of Mg on $Hg(C_6H_5)_2$ (132)

Unique conditions, reaction products:
Violent reaction in H_2O or steam (195).

Flammability:
Spontaneously flammable in moist (not dry) air (195).

DIMETHYL MANGANESE

Mol. Wt.:
84.96

Formula:
 $[(CH_3)_2Mn]_n$

Synthesis:
 $MnI_2 + 2CH_3Li \rightarrow [(CH_3)_2Mn]_n$ (245)

Solubility:
i. ether; s. excess $CH_3Li \rightarrow Li[Mn(CH_3)_3]$ (245)

Flammability:
Spontaneously flammable (245)

BIS-CYCLOPENTADIENYL MANGANESE

Mol. Wt.:
185.13

Formula:
 $Mn(C_5H_5)_2$

B.P.:
245°C (226)

M. P.:
172° - 173°C (226)

Characteristics:
Crystals - amber,
paramagnetic (226)

V.P.:
 $(10^{-4}-10^{-5})^{100-130}$ (226)

Synthesis:

React sodium cyclopentadienide with anhydrous manganese dibromide in tetrahydrofuran or glycol dimethyl ether at reflux temperature in the absence of oxygen, followed by the removal of the solvent and sublimation at 130°C and 10⁻⁴ mm. 45% yield (184).

Unique conditions, reaction products:

Liberates cyclopentadiene and manganese dioxide or its salt on reaction with H₂O, aqueous bases or acids (184).

Solubility:

sl. s. CS₂, CCl₄, chloroform (slow reaction); moderately s. benzene, ether, cyclohexane; very s. pyridine, tetrahydrofluoride (184)

Thermodynamic properties:

heat of fusion: 6.3 kcal/mol
specific conductivity: 1.4 x 10⁻⁵(NH₃) (at -33°C) } (226).
heat of vaporization: 12.0 kcal/mol
heat of sublimation: 17.3 kcal/mol }

Military and industrial uses:

Used in gas plating of heated surfaces in a vacuum (92)

Flammability:

Spontaneously flammable (226).

SODIUM NITROMETHANE

Mol. Wt.:
83.3

Formula:
NaCH₂NO₂

Unique conditions, reaction products:

Na or K salts of nitromethane exploded when dry salt was moistened with a little H₂O (143).

METHYL SODIUM

Mol. Wt.:
38.00

Formula:
CH₃Na

M. P.:
200°C (226)

Characteristics:
Solid (226)

Solubility:

i. organic; d. air, H₂O (226)

Flammability:

Spontaneously flammable (226).

SODIUM METHYLATE

<u>Mol. Wt.:</u>		<u>Formula:</u>
54.03		CH ₃ ONa
<u>d./sp. gr.:</u>		<u>Characteristics:</u>
4.6 lbs/gal (132)		Powder - white (132).
<u>Solubility:</u>		
d. H ₂ O (132).		
<u>Military and industrial uses:</u>		
Organic synthesis (132)		
<u>Flammability:</u>		
Spontaneously flammable in moist air (143).		

SODIUM ACETATE

<u>Mol. Wt.:</u>		<u>Formula:</u>
82.03		CH ₃ C(O)ONa
<u>M. P.:</u>		<u>Characteristics:</u>
324°C (195)		Crystal - white (195)
<u>d./sp. gr.:</u>		<u>n_D</u>
1.528 (195)	1.464	(79)
<u>Solubility:</u>		
sl. s. alcohol; s. H ₂ O, organic polymers; i. organic solvents		(79)
<u>Military and industrial uses:</u>		
Buffer in photography, mordant in dyeing (132).		
<u>Flammability:</u>		
Possible spontaneous flammability in moist air or H ₂ O		(27)

ETHYL SODIUM

<u>Mol. Wt.:</u>		<u>Formula:</u>
52.06		NaC ₂ H ₅
<u>M. P.:</u>		<u>Characteristics:</u>
Decomposes (226)		Crystal - white (226)
<u>Solubility:</u>		
d. H ₂ O, alcohol, ether, air; i. organic; s. diethyl zinc		(226)

Flammability:

Spontaneously flammable (226)

BENZYL SODIUM
(Solid)Mol. Wt.:

114.06

Formula: $C_6H_5 \cdot CH_2 \cdot Na$ M. P.:

Decomposes (184)

Characteristics:

Powder - white (152)

Solubility:

s. ether (184)

Flammability:

Spontaneously flammable (50)

METHYL PHOSPHINE

Mol. Wt.:

48.03

Formula: CH_3PH_2 B.P.:

25°C (226)

Characteristics:

Gas - colorless (103)

V.P.:1.75⁰ (103)Toxicity:

Highly toxic on inhalation (195).

Unique conditions, reaction products:

Forms fairly volatile crystalline salts with HCl and HI (231).

Solubility:sl. d. H_2O , alcohol; s. ether (103)Flammability:

Spontaneously flammable (95).

DIMETHYL PHOSPHINE

Mol. Wt.:

62.05

Formula: $(CH_3)_2PH$ V.P.:

30-47 (226)

d./sp. gr.:

< 1 (195)

Characteristics:

Liquid - colorless (226)

B.P.:

25°C (226)

V.d.:

2.14 (195)

Toxicity:

High on ingestion and/or inhalation (195)

Solubility:

s. organic solvents; d. air (226)

Flammability:

Spontaneously flammable in air (195)

TRIMETHYL PHOSPHINE

Mol. Wt.:

76.08

Formula:

P(CH₃)₃

M. P.:

-85.9°C (103)

Characteristics:

Liquid - colorless (79)

d./sp. gr.:

<1 (79)

B.P.:

40°-42°C (79)

Toxicity:

Vapors of burning are highly toxic (246)

Synthesis:

Combine PCl₃ and CH₃MgBr and di-n-butyl ether, then distill phosphine quietly from the mixture in dry N₂ atmosphere following distillation of the ether; use of dry-oxygen-free atmosphere in preparation is essential (246)

Solubility:

i. H₂O; s. ether (79)

Thermodynamic properties:

heat of vaporization: 6.92 kcal/mol (103)

heat of combustion: 1004 ± 11 cal/g

enthalpy of combustion: 763.2 ± kcal/mol

enthalpy of formation: (liq) -30.1 kcal/mol; (gas) -23.2 kcal/mol

} (114)

Flammability:

Burns violently in the air (246).

DIETHYL PHOSPHINE

Mol. Wt.:

90.11

Formula:

(C₂H₅)₂PH

B.P.:

85°C (195)

d./sp. gr.:

<1 (195)

Characteristics:

Liquid - colorless (103)

V.d.:

3.11 (195)

Toxicity:

High on ingestion or inhalation (195)

Solubility:

s. organic solvents (103)

Flammability:

Spontaneously flammable in air (195).

TRIFLUOROMETHYL PHOSPHINE

Mol. Wt.:

102.00 (226)

Formula:

F_3CPH_2

Characteristics:

gas (226)

B.P.:

-25.5°C (226)

Flammability:

Spontaneously flammable (226)

BIS-TRIFLUOROMETHYL CHLOROPHOSPHINE

Mol. Wt.:

204.44

Formula:

$(F_3C)_2PCl$

Characteristics:

Liquid - colorless (103)

B.P.:

21°C (79)

Solubility:

d. H_2O (79), alkaline solvents (103); s. organic polymers (103)

Flammability:

Spontaneously flammable (79).

BIS-TRIFLUOROMETHYL PHOSPHINE

Mol. Wt.:

170.01

Formula:

$(CF_3)_2PH$

Characteristics:

Gas - colorless (226)

B.P.:

1°C (226)

Solubility:

s. organic polymers (226)

Flammability:

Spontaneously flammable (226)

BIS-TRIFLUOROMETHYL CYANOPHOSPHINE

Mol. Wt.:

195.00

Formula:

$(F_3C)_2PCN$

$n_{D_2}^{20}$
1.3248 (79)

Characteristics
Liquid - colorless (79)

B.P.:
48°C (79)

Solubility:

s. organic polymers; i. H₂O (103).

Flammability:

Spontaneously flammable (79)

TRIS-TRIFLUOROMETHYL PHOSPHINE

Mol. Wt.:
238.01 (226)

Formula:
(CF₃)₃P

Characteristics
Liquid - colorless (226) B.P.:
17.3°C (226)

Solubility:

d. H₂O; s. organic polymers (226)

Thermodynamic properties:

heat of vaporization: 5890 cal/mol (226)

Flammability:

Spontaneously flammable (79)

TRIBUTYL PHOSPHINE

Mol. Wt.:
202.32

Formula:
P(C₄H₉)₃

F.P.:
-60° to -65°C (190)

B.P.:
245°C (190)

V.P.:
50¹²⁶ (103)

d./sp. gr.:
.8100²⁵₄ (190)

$n_{D_4}^{25}$
1.4588 (190)

Ignition temperature:

flash point: 40°C

fire point: 43°C

autoignition temperature: 260°C

} (190)

Solubility:

Almost i. H₂O; miscible with ether, methanol, ethanol and benzene (190)

Military and industrial uses:

Fuel additive; epoxy resin curing catalyst; vinyl and isocyanate polymerization; inorganic intermediate (190)

Flammability:

Spontaneously flammable in air (217)

1, 1, 3-TRIETHYL ETHOXY DIPHOSPHINYL OXIDE

Mol. Wt.:

210.20

Formula:

(C₂H₅)₂POP(C₂H₅)(OC₂H₅)

V.P.:

15⁹¹⁻⁹³ (103)

d./sp. gr.:

1.00042²⁰ (103)

Characteristics:

Liquid - colorless (103)

n_D²⁰:

D₄ (103)
1.4868

Solubility:

s. organic; d. H₂O, air (103)

Flammability:

Spontaneously flammable (103)

ANTIMONY TRIMETHYL

Mol. Wt.:

166.86

Formula:

(CH₃)₃Sb

Synonyms:

Trimethyl stibine

M.P.:

-87. 6°C (103)

Characteristics:

Liquid (195)

d./sp. gr.:

1.523¹⁵ (79)

B.P.:

80. 6°C (79)

Unique conditions, reaction products:

Reacts vigorously with oxidizing materials (195).

Solubility:

sl. s. cold and hot H₂O; s. ether; i. alcohol (79)

Thermodynamic properties:

heat of vaporization: 7.82 kcal/mol

heat of formation: -1.4 kcal/mol

heat of combustion: 698 kcal/mol

heat of combustion: 4172 ± 18 cal/g

enthalpy of combustion: 698.0 ± 31 kcal/mol

enthalpy of formation: (liq) -1.4 kcal/mol

} (103)
} (114)

Flammability:

Spontaneously flammable in air (195)

TRIMETHYL ANTIMONY SULFATE

Mol. Wt.:

262.85

Formula:

(CH₃)₃SbSO₄

Flammability:

Spontaneously flammable in air (14).

TRIVINYL STIBINE

Mol. Wt.:
202.90Formula:
 $(CH_2:CH)_3Sb$ Characteristics:
Liquid - colorless (103)B.P.:
149.9°⁷²² (103)Solubility:

s. organic solvents (241)

Flammability:

Spontaneously flammable (241)

ANTIMONY TRIETHYL

Mol. Wt.:
208.94Formula:
 $Sb(C_2H_5)_3$ Synonyms:
Triethyl stibineM.P.:
< -29°C (79)Characteristics:
Liquid (79)B.P.:
159.5°C (79)d./sp. gr.:
1.324¹⁶ (79) $\frac{n^{15}}{D}$ (79)
1.42Solubility:i. H₂O; s. alcohol, ether (79)Thermodynamic properties:

heat of combustion: 5552 ± 6 cal/g

enthalpy of combustion: 1162.6 ± 1.2 kcal/mol

enthalpy of formations: (liq) 2.3 kcal/mol; (gas) 13.1 kcal/mol

}

(114)

Flammability:

Spontaneously flammable (195).

TRIETHYL ANTIMONY SULFATE

Mol. Wt.:
304.88Formula:
 $Sb(C_2H_5)_3SO_4$ Flammability:

Spontaneously flammable in air (14).

PHENYLDIMETHYL ANTIMONY

Mol. Wt.:

228.93

Formula:

C₆H₅Sb(CH₃)₂

Characteristics:

Liquid - colorless oil (79)

B.P.:

112-15-18 (79)

Flammability:

Fumes in air (79)

TRIPROPYL ANTIMONY

Mol. Wt.:

250.85

Formula:

Sb(C₃H₇)₃

M.P.:

80-81°C (50)

Flammability:

Ignites or carbonizes on filter paper (52).

TETRAMETHYL DISTIBINE

Mol. Wt.:

303.56

Formula:

(CH₃)₂SbSb(CH₃)₂

M.P.:

175°C (37)

V.P.:

18¹⁰⁰ (37)

Synthesis:

Reaction of methyl radicals (from tetramethyl lead by pyrolysis) and an antimony mirror (37).

Flammability:

Spontaneously flammable (37)

BIS-DIMETHYLBISTIBINE OXIDE

Mol. Wt.:

319.56

Formula:

[(CH₃)₂Sb]₂O

Synthesis:

Hydrolyze (CH₃)₂SbBr with alkali (36)

Flammability:

Spontaneously flammable (36)

METHYL TRICHLORO SILANE

<u>Mol. Wt.:</u>	<u>Formula:</u>
149.50	CH ₃ SiCl ₃
<u>M. P.:</u>	<u>Characteristics:</u>
-77.8°C (103)	Liquid - colorless (acrid odor) (103)
<u>d./sp. gr.:</u>	<u>V.P.:</u>
1.273 ²⁵ 25 (103)	10 ⁻²⁷ (103) 60 ³
<u>B.P.:</u>	<u>Viscosity:</u>
66.4°C (103)	.37 cs (at 25°C) (103)
<u>n_D²⁵:</u>	
1.415	

Unique conditions, reaction products:

Evolves white fumes with moist air; violent reaction with H₂O yields heat and white acrid fumes (54)

Ignition temperature:

flash point: 45°F
autoignition temperature: 410°C } (103)

Solubility:

s. organic solvents; d. H₂O, alcohol (103)

Thermodynamic properties:

heat of vaporization: 84.9 Btu/lb
surface tension: 20.3 dynes/cm
specific heat: .22
coefficient of expansion: .0013 } (103)

VINYL TRICHLORO SILANE

<u>Mol. Wt.:</u>	<u>Formula:</u>
161.51	SiC ₂ H ₃ Cl ₃
<u>M. P.:</u>	<u>Characteristics:</u>
-95°C	Liquid - colorless (acrid odor) (103)
<u>d./sp. gr.:</u>	<u>V.P.:</u>
1.264 ²⁵ 1.265 ²⁰ (103)	10 ⁻¹¹ 60 ²³ 100 ³⁴ } (103)
<u>B.P.:</u>	<u>Viscosity:</u>
91°-93°C (103)	<u>n_D²⁵:</u> 1.432 (103)
<u>Viscosity:</u>	
.50 cs (at 25°C) (103)	<u>n_D²⁰:</u> 1.4365 (103)

Unique conditions, reaction products:

Evolves white fumes with moist air; violent reaction with H₂O (yields heat and white acrid fumes) (54).

Ignition temperature:

flash point: 70°F (103)

Solubility:

s. organic solvents; d. H₂O, alcohol (103)

Thermodynamic properties:

coefficient of expansion: .0016/°C	}
heat of vaporization: 88 Btu/lb	
specific heat: .20	

(103)

ETHYL TRICHLOROSILANE

umes) (5

Mol. Wt.:

163.51

Formula:

C₂H₅SiCl₃

M. P.:

-105.6°C (184)

Characteristics:

Liquid - colorless
(acrid odor) (103)

Viscosity:

.48 cs (at 25°C) (103)

d./sp. gr.:

1.238²⁰₄ (103)

B.P.:

97-103⁷⁶⁰ (103)

²⁰
n_D:

1.4257 (103)

Unique conditions, reaction products:

Evolves white fumes with moist air; violent reaction with H₂O (yields heat and white acrid fumes) (54).

Ignition temperature:

flash point: 80°F (103)

Solubility:

d. H₂O, alcohol (103)

Thermodynamic properties:

heat of vaporization: 99 Btu/lb	(103)
coefficient of expansion: .0015/°C	

DIMETHYL DICHLOROSILANE

Mol. Wt.:

129.07

Formula:

(CH₃)₂SiCl₂

M. P.:

-76°C (103)

Characteristics:

Liquid - colorless
(acrid odor) (103)

V.P.:

10⁻²⁵

(103)

606.5

<u>d. / sp. gr.:</u> 1.070 ²⁵ ₂₅ (103)	<u>B. P.:</u> 70.5°C (103)	<u>Viscosity:</u> .47 cs (at 25°C) (103)
	n ²⁵ <u>D_t</u> 1.405 (103)	

Unique conditions, reaction products:

Evolves white fumes with moist air; violent reaction with H₂O (yields heat and white acrid fumes) (54).

Ignition temperature:

autoignition temperature: 410°C (103)
flash point: 15°F

Solubility:

s. organic solvents; d. H₂O, alcohol (103).

Thermodynamic properties:

heat of vaporization: 99.4 Btu/lb	}	(103)
surface tension: 20.1 dynes/cm		
coefficient of expansion: .0013/°C		

TRIMETHYL CHLOROSILANE

<u>Mol. Wt.:</u> 108.65	<u>Formula:</u> (CH ₃) ₃ SiCl	
<u>M. P.:</u> -57.7°C (103)	<u>Characteristics:</u> Liquid - colorless (acrid odor) (103)	<u>V. P.:</u> 10 ⁻³⁴
<u>d. / sp. gr.:</u> .854 ²⁵ ₂₅ (103)		60 ⁻⁴
<u>.846²⁵₄</u>	<u>B. P.:</u> 57.9°C (103)	100 ⁶
<u>Surface tension:</u> 9.5 dynes/cm (at 20°C) (103)	<u>Viscosity:</u> .47 cs(at 25°C) (103)	400 ^{39.4}

Unique conditions, reaction:

Evolves white fumes with moist air; violent reaction with H₂O (yields heat and white acrid fumes) (54)

Ignition temperature:

flash point: -16°F
autoignition temperature: 400°F (103)

Solubility:

s. organic solvents (103)

PROPYL SILANE

103)

Mol. Wt.: 74.20 Formula: Si(C₃H₇)H₃

d./sp. gr.: .6434²⁰₄ (103) Characteristics: Liquid - colorless (103) $\frac{n^{20}}{D_t}$ $\frac{1.3759}{1.3759}$ (103)

B.P.:
23°C (103)

Solubility:
s. organic solvents; i. H₂O (103)

Thermodynamic properties:
heat of combustion: 19,000 Btu/lb (202)

Flammability:
Spontaneously flammable (103).

DIETHYL DICHLOROSILANE

Mol. Wt.: 157.13 Formula: (C₂H₅)₂SiCl₂

M.P.: -96.5°C (184) Characteristics: Liquid - colorless (103) V.P.: $\frac{100^{69}}{10^{21}}$ (103)

d./sp. gr.: 1.0504²⁰₄ (79) B.P.: 129°C (79) $\frac{n^{20}}{D_t}$ $\frac{1.4809}{1.4809}$ (79)

Unique conditions, reaction products:
Fumes strongly in moist air, so intense that leaky containers appear to be on fire (54).

Solubility:
d. cold H₂O; s. ether (79)

TETRAMETHYL SILANE

Mol. Wt.: 88.23 Formula: (CH₃)₄Si

M.P.:
 α -101.7°C (226)
 β -99.5°C Characteristics: Liquid - colorless (226) $\frac{n^{20}}{D_t}$ $\frac{1.3582}{1.3582}$ (226)

d./sp. gr.:
.6688⁰₄ (226)
.6480²⁰₄ (226) B.P.: 26.2°C (226)

Solubility:s. organic solvents; i. H₂O (226)Thermodynamic properties:

heat of vaporization: 6.25 kcal/mol (at 26.2°C)
 heat of formation: (liq) -69 kcal/mol; (gas) -63 kcal/mol
 heat of combustion: -920 kcal/mol

 $\}$ (226)Flammability:

Spontaneously flammable (226).

AMYL TRICHLOROSILANEMol. Wt.:
205.60Formula:
SiC₅H₁₁Cl₃d./sp. gr.:
 $\frac{n^{25}}{D} = 1.3725$ (103)Characteristics:
Liquid - colorless (103)V.P.:
 $120 \cdot 10^7$ (103) n^{25}_D :
 $\frac{n^{25}}{D} = 1.4415$ (103)B.P.:
166°-169°C (103)Viscosity:
1.10 cs (at 25°C) (103) n^{20}_D :
 $\frac{n^{20}}{D} = 1.445$ (103)Unique conditions, reaction products:

Fumes strongly in moist air (54).

Ignition temperature:

flash point: 135°F (103)

Solubility:s. organic solvents; d. H₂O (103)Thermodynamic properties:

specific heat: .35
 coefficient of expansion: .0014/°C

BENZYL SILANEMol. Wt.:
122.25Formula:
C₆H₅·CH₂SiH₂ $\frac{n^{25}}{D}$:
 $\frac{n^{25}}{D} = 1.505$ (103)Characteristics:
Liquid - colorless (103)V.P.:
 305^3 (103)

Solubility:

i. H₂O; s. organic solvents (103)

Thermodynamic properties:

heat of combustion: 19,000 Btu/lb (202)

Flammability:

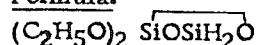
Spontaneously flammable (202)

DIETHOXYSILOXENE

Mol. Wt.:

226.43

Formula:



Solubility:

d. H₂O (103)

Flammability:

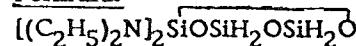
Spontaneously flammable (103)

BIS(ETHYLAMINO) SILOXENE

Mol. Wt.:

280.57

Formula:



Characteristics:

Solid - orange (226)

Solubility:

d. H₂O, air (226)

Flammability:

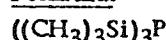
Spontaneously flammable (226).

TRISTRIMETHYLSILYL PHOSPHINE

Mol. Wt.:

250.33

Formula:



Characteristics:

Liquid (157)

B.P.:

253°C (157)

Synthesis:

React NaPH₂ and (CH₃)₃SiCl in an ether solvent at room temperature and distill in a spinning band column (157).

Flammability:

Spontaneously flammable (157).

TRIETHYL TELLURIUM

<u>Mol. Wt.:</u>	<u>Formula:</u>
214.67	$\text{Te}(\text{C}_2\text{H}_5)_3$
<u>M. P.:</u>	<u>Characteristics:</u>
138°C (52)	Liquid - reddish yellow (52)
<u>Flammability:</u>	Spontaneously flammable in air (52).

ISOBUTYL TITANIUM TRICHLORIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>
211.29	$\text{i-C}_4\text{H}_9\text{TiCl}_3$
<u>M. P.:</u>	<u>Characteristics:</u>
	Solid (128)

<u>Flammability:</u>
Nearly pyrophoric (128).

TRIMETHYL THALLIUM

<u>Mol. Wt.:</u>	<u>Formula:</u>	
249.38	$(\text{CH}_3)_3\text{Tl}$	
<u>M. P.:</u>	<u>Characteristics:</u>	<u>V. P.:</u>
38.5°C (226)	Needles - colorless (226)	520 (226).

B. P.:
147°C (extrapolated) (226).

<u>Solubility:</u>
d. light, H_2O ; s. organic solvent (226).

<u>Flammability:</u>
Spontaneously flammable (226).

PHENYL DICYCLOPENTADIENYLVANADIUM

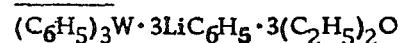
<u>Mol. Wt.:</u>	<u>Formula:</u>
258.11	$(\text{C}_5\text{H}_5)_2\text{VC}_6\text{H}_5$
<u>Flammability:</u>	Spontaneously flammable in air (243)

TRIPHENYL TUNGSTEN-TRIS(PHENYL LITHIUM)-TRIS(DIETHYL ETHER)

Mol. Wt.:

875.81

Formula:



Characteristics:

Violet (226)

Solubility:

s. organic solvent; d. H₂O, alcohol (226).

Flammability:

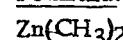
Spontaneously flammable (226).

ZINC DIMETHYL

Mol. Wt.:

95.45

Formula:



M. P.:

-42°C (224)

Characteristics:

Liquid - colorless (226)

V.P.:

124° (226).

d./sp. gr.:

1.386¹⁰ (226)

B.P.:

46°C (226)

Thermodynamic properties:

heat of combustion: 5050 ± 15 cal/g

enthalpy of combustion: 433.2 ± 1.4 kcal/mol

enthalpy of formation: (liq) 6.5; (gas) 13.3 kcal/mol

}

(114)

Flammability:

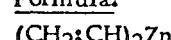
Spontaneously flammable in air (226).

DIVINYL ZINC

Mol. Wt.:

119.42

Formula:



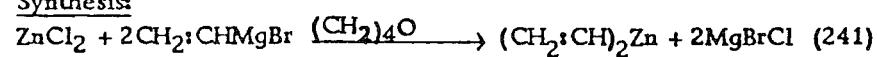
B.P.:

32²² (241)

Unique conditions, reaction products

Yield ethylene on contact with H₂O (241).

Synthesis:



Flammability:

Spontaneously flammable in air (241).

ZINC ISOBUTYL

Mol. Wt.:	Formula:
179.6	$\text{CH}_3(\text{CH}_2)_3\text{Zn}$

Unique conditions, reaction products:

Reacts with H_2O to yield ethane (27).

Flammability:

Spontaneously flammable (27).

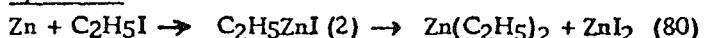
DIETHYL ZINC

Mol. Wt.:	Formula:	
123.50	$\text{Zn}(\text{C}_2\text{H}_5)_2$	
M. P.:	Characteristics:	V.P.:
-30°C (226)	Liquid - colorless (226)	27 ³⁰ (226)
d./sp. gr.:	B.P.:	n _D ²⁰
1.182 ¹⁸ (226)	117.6°C (226)	1.4936 (226)

Toxicity:

When burning, yields zinc oxide fumes (threshold value 5 mg/m³) (142).

Synthesis:



Unique conditions, reaction products:

Extremely violent decomposition in H_2O to yield: $\text{Zn}(\text{OH})_2 + \text{C}_2\text{H}_5$ (80).

Solubility:

d. H_2O , alcohol; s. organic solvents (226)

Handling:

Ship in sealed tubes or steel cylinders, protect from physical damage, keep cool and dry (142).

Thermodynamic properties:

heat of formation: (liq) 5.2 kcal/mol; (gas) 142 kcal/mol
heat of combustion: 6481 ± 4 cal/g } (114)

Military and industrial uses:

Igniter for capsule firing flame thrower (99).

Flammability:

Spontaneously flammable in air (226).

ZINC ISOAMYL

Mol. Wt.: 136.43 Formula: $i\text{-CH}_3(\text{CH}_2)_4\text{Zn}$

Characteristics:
Liquid (27)

Unique conditions, reaction products:

Reacts with H_2O to yield C_2H_6 (27)

Flammability:

Spontaneously flammable (27).

DI-*n*-PROPYL ZINC

Mol. Wt.: 151.55 Formula: $\text{Zn}(\text{C}_3\text{H}_7)_2$

<u>d./sp. gr.:</u> $1.1034\frac{20}{4}$ (226)	<u>Characteristics:</u> Liquid (226)	<u>V.P.:</u> 10^{48} (226)
	<u>B.P.:</u> 160°C (226)	$n^{18.6}$ D_t 1.4845 (226)

Unique conditions, reaction products:

Reacts with H_2O to yield C_2H_6 (27)

Solubility:

d. H_2O ; s. organic solvents (226).

Thermodynamic properties:

heat of formation: (liq) -3.9 kcal/mol; (gas) -13.6 kcal/mol }
enthalpy of combustion: 1113.3 ± 5.6 kcal/mol } (114)

Flammability:

Spontaneously flammable (226).

TETRAMETHYL DIBORANE

Mol. Wt.: 83.79 Formula: $(\text{H}(\text{CH}_3)_2\text{BB}(\text{CH}_3)_2\text{H})$

<u>M. P.:</u> -73°C (103)	<u>Characteristics:</u> Liquid (103)	<u>B.P.:</u> 69°C (103)
--	---	--

Solubility:

s. organic solvent; d. H_2O , air (103).

Thermodynamic properties:

heat of combustion: 24,000 Btu/lb (202)

heat of vaporization: 7.3 kcal/mol (103)

Flammability:

Spontaneously flammable (200)

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(b) HALIDES

DI-CHLOROACETYLENE

<u>Mol. Wt.:</u> 94.93	<u>Formula:</u> $\text{ClC}\equiv\text{CCl}$	<u>Synonyms:</u> Dichloroethylene
<u>M. P.:</u> -66°C (79)	<u>Characteristics:</u> Gas (123)	<u>B. P.:</u> Explodes (79)

Synthesis:

Trichloroethylene with caustic soda decomposes to form di- or trichloroacetylene gas (123).

Solubility:

s. alcohol, ether (79)

Flammability:

Ignites or explodes on contact with air (123).

HEXA-CHLOROETHANE MIXTURE

<u>Mol. Wt.:</u> 236.76	<u>Formula:</u> CCl_3CCl_3	<u>Synonyms:</u> Perchloroethane Carbon hexachloride
<u>M. P.:</u> 186.6°C (sublimes) (132)	<u>Characteristics:</u> Solid - rhombic, triclinic or cubic crystals, colorless, camphor-like odor (132)	<u>Carbon trichloride</u> <u>Smoke powder</u>
<u>d./sp. gr.:</u> 2.091 (132)		<u>V.P.:</u> $1^{32.7}$ (195)

Toxicity:

Moderately irritating to skin, mucous membranes and liver. Narcotic in high concentrations (132).

Solubility:

i. H_2O ; s. alcohol, benzene, chloroform, ether, oils (132)

Military and industrial uses:

Solvent, in explosives, camphor substitute in celluloid rubber vulcanizing accelerator (132).

Flammability:

Moisture hazardous, ignites with water (27).

BROMOETHYNE

<u>Mol. Wt.:</u> 104.9	<u>Formula:</u> $\text{HC}\equiv\text{CBr}$	<u>Synonyms:</u> Bromacetylene Bromoacetylene Ethynyl chloride
---------------------------	--	---

d./sp. gr.:
.0047 (79)

Characteristics:
Gas (79)

V.d.:
4.684 g/cm³ (195)

B.P.:
4°C (79)
-2°C (195)

Solubility:

s. ether, dilute HNO₃, dilute HCl (79)

Flammability:

Spontaneously flammable in air (195)

CHLOROACETYLENE

Mol. Wt.:
60.48

Formula:
HC:CCl

Synonyms:
Chloroethyne
Ethanoyl chloride
Acetylene chloride

M.P.:
-126°C (79)

Characteristics:
Gas (195)

d./sp. gr.:
.002760 (195)

B.P.:
-32°C (79)

Toxicity:

Unknown (195).

Synthesis:

Can be formed from NaOH and trichloroethylene (123).

Unique conditions, reaction products:

Aqueous solution generates O₃ and glows in the dark (46).

Solubility:

d. H₂O; s. alcohol (79)

Flammability:

Unstable, spontaneously flammable (123).

ACETYL BROMIDE

Mol. Wt.:
122.95

Formula:
CH₃COBr

Synonyms:
Ethanoyl bromide
Acetic acid bromide

M.P.:
-96°C (79)

Characteristics:
Liquid - colorless fuming
(yellow in air) (195)

B.P.:
76.7°C (79)

<u>d./sp. gr.:</u>	$\frac{n^{16}_D}{4}$	(79)
1.66316 4	1.4538	

Toxicity:

High (acute local) as irritant, on ingestion and on inhalation (195).

Synthesis:

Interaction of CH_3COOH and PBr_5 (190).

Unique conditions, reaction products:

Violent decomposition with moisture (195).

Solubility:

d. H_2O , alcohol; s. ether, benzene, chloroform (79)

Military and industrial uses:

Organic synthesis and manufacture of dyes (190).

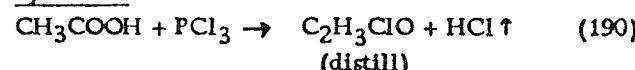
ACETYL CHLORIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
78.50	CH_3COCl	Ethanoyl chloride Acetic acid chloride
<u>M.P.:</u>	<u>Characteristics:</u>	<u>V.d.:</u>
-112°C (79)	Liquid - colorless, fuming (79)	2.7 (195)
<u>d./sp. gr.:</u>	<u>B.P.:</u>	<u>n²⁰ D:</u>
1.1039 ²¹ 4 (79)	51°-52°C (79)	(79) 1.3898

Toxicity:

High as irritant, on ingestion, and inhalation; when heated emits highly toxic fumes of phosgene (195).

Synthesis:



Unique conditions, reaction products:

Reacts violently on contact with H_2O or alcohol (190).

Solubility:

s. ether, acetone, acetic acid (190)

Handling:

Keep from water (132).

Military and industrial uses:

Used in organic synthesis (preparation of acetic anhydride, dyes and pharmaceuticals) (190).

BENZOYL CHLORIDE

Mol. Wt.:
140.5 (46)

Formula:
C6H5COCl

M. P.:
-1°C (46)

Characteristics:
Liquid - colorless -
fuming (46)

B. P.:
197°C
194742 (46)

d./sp. gr.:
1.2187₁₅¹⁵ (36)

n_D²⁰
D_t
1.55369 (46)

Unique conditions, reaction products:

Smokes in air (191), gives benzoyl derivatives with alcohols, phenols and amines (46).

Solubility:

s. C₆H₆, ether (191)

ANISOYL CHLORIDE

Mol. Wt.:
170.5

Formula:
CH3OC6H4COCl

Synonyms:
Anisic acid chloride

M. P.:
22°C (46)

B. P.:
160-164⁵⁵ (46)

Toxicity:

High (acute local irritant) on ingestion and on inhalation (195).

Unique conditions, reaction products:

Hydrolyzes to HCl with H₂O (195).

Solubility:

i. H₂O; s. acetone, ethane (195)

Military and industrial uses:

Intermediates for dyes and medicines (190).

Flammability:

Spontaneous explosion at room temperature (195).

TRI-CHLOROACETYLENE

Characteristics:
Gas

Synthesis:

Trichloroethylene with caustic soda decomposes to form di- or trichloroacetylene gas (123).

Flammability:

Ignites or explodes on contact with air (123).

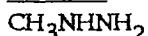
(c) MISCELLANEOUS

MONOMETHYLHYDRAZINE (MMH)

Mol. Wt.:

42.01

Formula:



M. P.:

-62.5°F (149)

Characteristics:

Liquid - clear, water-white, ammoniacal odor
(149)

V.P.:

.3140°F

1.080°F

3.1120°F

7.9160°F

} (149)

d./sp. gr.:

7.32 (at 68°F) (149)

Viscosity:

.85 (at 68°F) (149)

B.P.:

189.5°F (149)

$$\frac{n}{D_2} \quad (149)$$

$$1.59$$

Toxicity:

Caustic to skin and eyes, can affect respiratory system, potent central stimulant (tremors and convulsions); no threshold limit value set but it is probably below .5 ppm (149).

Unique conditions, reaction products:

Reacts with CO₂ and/or O₂ in air, hypergolic with H₂O₂, N₂O₄, F₂, HNO₃ (149)

Ignition temperature:

Open cup flash point: 61°-63°F; autoignition temperature: 382°F; flammability limit 2.5-92 or 98% (149)

Solubility:

Miscible with H₂O, lower weight alcohols, hydrazines (its derivatives) and amines; s. hydrocarbons (149).

Thermodynamic properties:

critical temperature: 562°F

critical pressure: 1180° psia

critical density: 1.42 g/cm³

} (149)

Flammability:

"... exposure of MMH in air on a large surface (e.g., rags) may result in spontaneous ignition from heat evolved by oxidation with atmospheric O₂" (149).

PRODUCTS OF NITRATION OF DINITROFLUOROETHANE

Unique conditions, reaction products:

Air admitted into vacuum at 60°C explosive reaction (9).

ETHYL NITRITE

<u>Mol. Wt.:</u>	<u>Formulas:</u>	<u>Synonyms:</u>
75.07	C ₂ H ₅ NO ₂	Nitrous ether
<u>d./sp. gr.:</u>	<u>B.P.:</u>	<u>V.d.:</u>
.9 (195)	16.4°C (195)	2.59 (195)

Toxicity:

Moderate (acute and chronic systemic) on inhalation (195).

Synthesis:

From action of ethyl alcohol on nitrous oxide gas; treat ethyl alcohol with alkali nitrites and sulfuric acid (190).

Ignition temperatures:

flash point: -31°F

ignition temperature: explodes at 194°F

} (195)

Thermodynamic properties:

heat of combustion (at critical pressure): 334.21 cal (46)

UNSYMMETRICAL DIMETHYL HYDRAZINE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>n_D:</u>
60.1 (195)	(CH ₃) ₂ NNH ₂	1.40753 (46)
<u>M.P.:</u>	<u>Characteristics:</u>	<u>V.P.:</u>
-58°C (195)	Liquid - ammoniacal odor (46)	157 ²⁵ (195)
<u>d./sp. gr.:</u>	<u>B.P.:</u>	<u>Viscosity:</u>
.782 (195)	63.3°C (195)	.56 cps (at 68°F) (153)

Toxicity:

Not as toxic as hydrazine, stimulates central nervous system, threshold limit approximately .5 ppm (153).

Synthesis:

(1) react dimethylamine and chloromine; (2) react dimethylamine salt with sodium nitrate then reduce product; (3) catalytic oxidation of dimethylamine and ammonia (190).

Ignition temperature:

flash point: 34°F (195)

autoignition temperature: 145.9°F (127)

Solubility:

s. H₂O, ethanol, (C₂H₅)₂O (46); completely miscible with H₂O, hydrazine, diethyl triamine, C₂H₅OH and most petroleum fuels (153).

Thermodynamic properties:

critical temperature: 482°F	}
critical pressure: 786 psia	
heat capacity (liq): 65Btu/lb	
coefficient of thermal expansion: .1 cp	
heat of vaporization: 72 Btu/lb (at F.P.)	

heat of combustion: 14,200 Btu/lb (75)

Military or industrial uses:

Jet and rocket fuel component, used in chemical synthesis, used as a stabilizer in organic fuel peroxides (190)

Flammability:

On a large surface may ignite due to slow air oxidation (153).

DIACETYLENE

<u>Mol. Wt.:</u> 50.1	<u>Formula:</u> <chem>HC:CC:CH</chem>	<u>Synonyms:</u> Butadiyne Butadiene
<u>M.P.:</u> -36.4°C (195)	<u>B.P.:</u> 10.3°C (195)	<u>n_D:</u> 1.43862 (46)
<u>d./sp. gr.:</u> 2.233 (195)		

Toxicity

Moderate as acute systemic (195).

Unique conditions, reaction products

Spontaneously explodes with damp silver salts (195).

Flammability:

Spontaneously flammable (27):

ACETYL PEROXIDE

<u>Mol. Wt.:</u> 118.1	<u>Formula:</u> $(CH_3CO)_2O_2$	<u>Synonyms:</u> Ethanoyl peroxide Diacetyl peroxide
<u>M.P.:</u> 30°C (195)	<u>Characteristics:</u> Solid - crystal - colorless (195)	<u>B.P.:</u> 63 ²¹ (195)
<u>d./sp. gr.:</u> 1.18 (195)	<u>V.d.:</u> 4.07 (190)	

Toxicity:

Moderate (acute local) as irritant, on ingestion, on inhalation (195).

Unique conditions, reaction products:

Can cause ignition of organic materials on contact, produces heat on contact with water or steam (195).

Ignition temperature:

Above 122°F a violent decomposition may occur (142); flash point: 113°F (190)

Solubility:

s. H₂O, alcohol, ether; d. NaOH, CCl₄ (190)

Handling:

Keep from physical damage, no sources of ignition (electrical) to be located in the building, temperature range 32°F-90°F (142).

Military and industrial uses:

Initiator and catalyst for resins (190)

Flammability:

Spontaneously flammable if more than 24 hours old (195).

P-NITROSOPHENOL

Mol. Wt.:

123

Formula:

C₆H₄OHNO

M. P.:

144°C (46)

Characteristics:

Solid - pale yellow needles (46)

Synthesis:

From phenol by action of cold nitrous acid (190)

Unique conditions, reaction products:

Ignites with small amounts of acid or alkali (190)

Solubility:

s. alcohol, ether, acetone; moderately s. H₂O (190)

Thermodynamic properties:

heat of combustion: 715.5 cal (46)

Flammability:

Impure - explodes by self-ignition (190)

PHENYLDIAZOSULFIDE

Mol. Wt.:

138.12

Formulat

C₆H₅NNSH

Characteristics:

Solid - red (163)

Unique conditions, reaction products:

Explodes when dried in air (163)

STYRENE OXIDE

Mol. Wt.:

120.15

Formula:

C₈H₈O

Synonyms:

Phenylloxiran

Benzene, 1,2epoxylethyl

d./sp. gr.:

1.0523¹⁶₄ (79)

Characteristics:

Liquid (79)

B.P.:

381.6°F (129)

Ignition temperature:

flash point: 175°F

autoignition temperature: 175°F

}

(129)

Solubility:

i. H₂O; s. alcohol, ether (79)

2-ETHYLHEXALDEHYDE

Mol. Wt.:

128.21

Formula:

CH₃(CH₂)₃CH(C₂H₅)CHO

Synonyms:

2-ethyl hexanal

M.P.:

< -100°C (79)

Characteristics:

Liquid (195)

V.P.:

1.820 (195)

d./sp. gr.:

.8205 (195)

B.P.:

163°60 (79)

V.d.:

4.42 (195)

Ignition temperature:

flash point (open cup): 125°F (195)

Solubility:

i. H₂O; s. alcohol, ether (79)

Flammability:

Spontaneously flammable in air (217)

STEARIC ACID

Mol. Wt.:

284.49

Formula:

CH₃(CH₂)₁₆CO₂H

Synonyms:

Octadecanoic acid

M.P.:

70.1°C (79)

Characteristics:

Solid -monoclinic
leaf (79)

n³⁰_{D:}

1.4299 (79)

d./sp. gr.:
.9408²⁰₄ (79)

B.P.:
183.5°C (79)

Unique conditions, reaction products:

Heats spontaneously (129)

Ignition temperature:

flash point: 385°F
autoignition temperature: 743°F (129)

Solubility:

i. H₂O; o^o alcohol, ether, acetone, C₆H₆; s. chloroform, CCl₄, CS₂ (79)

TRIDECYL ALDEHYDE

Mol. Wt.:
198.35

Formula:
CH₃·[CH₂]₁₁CHO

Synonyms:
Tridecanal

M.P.:
14°C (46)

B.P.:
126-128¹⁰ (46)

n_D¹⁸: (46)
1.4384

d./sp. gr.:
.8356¹⁸₄ (46)

Solubility:

i. H₂O; s. alcohol (79)

Flammability:

Spontaneously flammable in air (217)

DIAZIRINE

Unique conditions, reaction products:

Explosive with air (10)

DIMETHYL DIMETHYL PHOSPHORAMIDATE

Characteristics:
Liquid (127)

B.P.:
136°F (127)

Unique conditions, reaction products:

Sensitive to O₂ and moisture (127)

O, O DIMETHYL THIOPHOSPHORYL CHLORIDE

Characteristics:
Liquid (127)

Unique conditions, reaction products:

Unstable above 30-40°C, furnes, may explode at 100°C (127)

Ignition temperature:

autoignition temperature: 212°F (127)

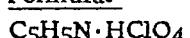
3 PYRIDINE-DIAZONIUM FLUOROBORATE

Flammability:

When completely dry - violent spontaneous decomposition (47)

PYRIDINIUM PERCHLORATE

Formula:



Synthesis:

Formed during purification of pyridine with HClO_4 (113)

Flammability:

Violent explosion in air (113).

VINYLMETHYL TETRAZOLE TRIBORANE

Unique conditions, reaction products:

Spontaneous decomposition takes place at room temperature (5).

III. MISCELLANEOUS COMPOUNDS

Uranium Borohydride Decomposition Residue

Flammability:

Air reactive (197)

Aluminum and Iodine
(equal amounts)

Flammability:

Spontaneously inflames with H₂O (9)

Trimethyl Amine and Lithium Aluminum Hydride Addition Compound

Synthesis:

Excess trimethyl amine reacts with an etheral solution of LiAlH₄ in vacuo at -50°C to yield a white addition compound (163).

Solubility:

s.l. s. ethane; i. C₆H₆ (163)

Flammability:

Spontaneously flammable in air (163)

Phenyl Derivative

Synthesis:

An unstable white solid phenyl derivative is formed from the action of phenylmagnesium bromide on silver chloride or bromide in ether. The substance may be isolated but on evaporation of the solvent the dry solid decomposes in a puff of white smoke (184).

P≡C-H Polymer

Synthesis:

P≡C-H at temperatures over -124°C forms extremely pyrophoric polymers (240).



Flammability:

With moisture spontaneous heating and ignition may occur (63).

Tributyl Borine and Borontrichloride Reaction Products

Synthesis:

Heat .14 moles tributyl borine with .31 moles borontrichloride at 200°C for 4 hours and 380°C for 1 hour. Reaction yields low boiling gases and a pyrophoric mixture of products boiling between 25° and 100°C (203).

C_6H_5HgCl and $CrCl_3 \cdot 3THF$ Reaction Products

Synthesis:

Heat $3C_6H_5HgCl + CrCl_3 \cdot 3THF$ at: (1) Atmospheric pressure and temperatures greater than $60^\circ C$, (2) at room temperature and reduced pressure, then (3) wash red solid with diethyl ether to yield black pyrophoric, paramagnetic solid (244).

Unique conditions, reaction products:

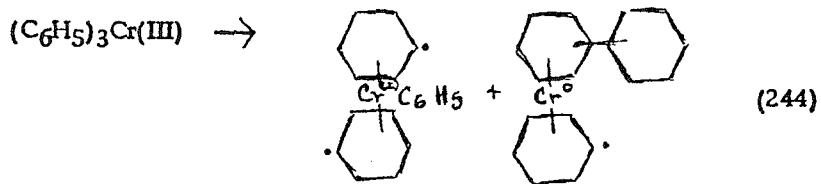
Hydrolysis of black powder yields bis-crene-complexes (244)

Flammability:

Spontaneously flammable (244).

Structure:

Black solid considered to be composed of approximately equal parts of bis-benzene- and benzene-biphenyl-chromium intermediates possible structure:



Difluorourea Decomposition Products

Unique conditions, reaction products:

Difluorourea decomposition products in air are a possible cause of fire (6)

Uranium Borohydride and Trimethyl Boron Reaction Products

Synthesis:

Uranium borohydride and trimethyl boron in a sealed tube at $60^\circ C$ for 4 hours yields a non volatile finely divided brown deposit (197).

Flammability:

Vigorous reaction with air (197).

Aluminum Borohydride Decomposition Products

Synthesis:

Evaporate aluminum borohydride rapidly at room temperature, a residue remains which contains Al, B, and active H_2 (196).

Flammability:

Detonates spontaneously in air (196).

Magnesium Silicide and Acid (Usually Dilute HCl) Reaction Products

Flammability:

Spontaneously flammable (50).

60°C,
solid black

Zinc and Iodine
(equal amounts)

Flammability:

Spontaneously flammable in H₂O (3).

benzene -

Magnesium and Iodine
(equal amounts)

Flammability:

Spontaneously inflames with H₂O (3).

Rosin

M.P.:

100-150°C (195)

Formula:

80-90% abietic acid
5.6% anhydride

Synonyms:

Pice resin
Colophony
Gum rosin

d./sp. gr.:

1.08²⁵ (195)

Characteristics:

Pale yellow to amber -
translucent fragments - turpentine odor and taste (195)

Synthesis:

Obtained as exudate, mixed with volatile oil, by incision of coniferous trees (distill off turpentine) (214).

volatile

Unique conditions, reaction products:

Can react with oxidizing materials (195).

Ignition temperature:

flash point: 370°F (195)

Solubility:

s. alcohol, ether, C₆H₆, glacial acetic acid, many oils, and aqueous alkaline solvents; i. H₂O (190)

Military and industrial uses:

Forms soaps with aqueous alkali; dark products used in linoleum, rosin oil and dark varnishes, next series used in making size for paper; lighter grades in soap manufacture, used in resinites of Pb, Co, etc., as a paint drier, sealing wax or plastic (190)

Flammability:

Spontaneously flammable in air (195).

Toxicity:

Slight as allergen (195).

Trimethyl Aluminum -Dimethyl Ether Complex

M.P.:
-29.9°C (226)

B.P.:
159°C (226).

Flammability:

Spontaneously flammable (226).

Hydrogen Phosphide and Impurities

Flammability:

Spontaneously flammable in air (62).

Oleum

Formula:
 H_2SO_4 with free SO_3

Synonyms:
Fuming sulfuric acid

Characteristics:

Liquid - viscous, colorless, or slightly colored (25)

Unique conditions, reaction products

With moisture in air yields a white fog (25).

Military and industrial uses:

Used in World War I by Germans as a smoke screen, used by Germans in World War II in floating smoke pots (reacts with H_2O) (25). Sulfonating agent in production of organic compounds (214).

Titanium and Nitric Acid

Flammability:

Spontaneously flammable (74).

Bismuth Hydroxide and Aluminum Hydroxide

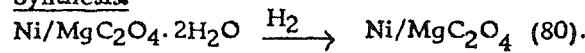
Synthesis:

$Bi(OH)_3$ and $Al(OH)_3$ coprecipitated and reduced by H_2 at 170°-210°C is spontaneously flammable at ordinary temperatures (143).

Ni-Mg Mixed Oxalate Catalyst

Formula:
 Ni/MgC_2O_4

Synthesis



Flammability:

Spontaneously flammable (80).

Aluminum Powder and Sodium Peroxide
(mixture)

Unique conditions, reaction products:

Ignites with H_2O (3)

"FS" Solution of Sulfuric Trioxide in Chlorosulfonic Acid

Unique conditions, reaction products:

Atomized in moist air, ingredients reacted with water vapor to form minute droplets of H_2SO_4 which appeared as a dense white cloud (26).

Military and industrial uses:

Used as smoke screen in World War II (26).

Sodium Peroxide and Sodium Thiosulfate
(mixture)

Unique conditions, reaction products:

Ignites with H_2O (4).

$\text{Si}_2\text{Cl}_2 + \text{NH}_3$ Reaction products

Synthesis:

React $\text{Si}_3\text{Cl}_6 + \text{NH}_3 \rightarrow \dots$ (227)

Flammability:

Spontaneously flammable (227)

Aluminum Iodide and Sodium Peroxide

Unique conditions, reaction products:

Water-reactive smoke signal igniter (227)

Silane Gas

Unique conditions, reaction products:

Aluminum chloride and calcium silicide reacts with H_2O to yield spontaneously flammable silane gas (227).

Nitroso Chloride of Alphamethylstyrene

Flammability:

"Slow decomposition in air (in screw topped bottle) finally heat evolved or decomposition products accumulated to the point that the reaction was accelerated and sufficient pressure was built up to force the cap from the bottle, white smoke filled the room" (7).

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Jack R. Gibson
Jeanne D. Weber

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13. ABSTRACT

The Handbook of Selected Properties of Air-Reactive and Water-Reactive Materials represents the work resulting from the literature search covering the years 1950 through 1968. Data are presented on the following properties of the pertinent compounds molecular weight, melting point, characteristics, boiling point, vapor pressure, synthesis, solubility, thermodynamic properties and flammability. In addition, attention is paid to other characteristics such as toxicity, handling and military and industrial uses.

The material is arranged in three parts Part I. Inorganic Compounds, Part II. Organic Compounds, and Part III. Miscellaneous Compounds (analyzing complex compounds, mixtures and byproducts of chemical reactions).

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