RDTR No. 144

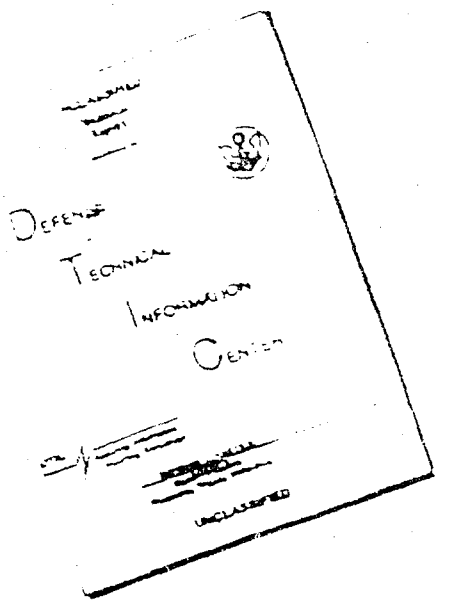
March 1969

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

U. S. NAVAL AMMUNITION DEPOT

CRANE, INDIANA

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

U. S. Naval Ammunition Depot
Crane, Indiana 47522

RDTR No. 144

March 1969

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

by

Jack R. Gibson
Joanne D. Weber

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

Released

S. M. Fasig
Concept Development Division
Research and Development Department

RDTR No. 144

UNCLASSIFIED

HANDBOOK OF SELECTED PROPERTIES OF AIR- AND WATER REACTIVE MATERIALS

Final Report
January 1966 - December 1968

Jack R. Gibson
Joanne D. Weber

Prepared Under Contract PO-6-0024 for the Research and Development Department, U. S. Naval Ammunition Depot, Crane, Indiana, 47522, by the Special Bibliographies Section, Science and Technology Division, Library of Congress, Washington, D. C. 20450.

TABLE OF CONTENTS

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).

FOREWORD

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.

Acknowledgments

The compilation of the Handbook was supervised by Dr. Clement R. Brown, Head, Special Bibliographies 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

Mol. Wt.:	Formula:	
107.87	Ag	
M.P.:	Characteristics	V.P.:
960.8°C (79)	Solid - white cubic metal (79)	10^{1575} (79)
d./sp. gr.:	B.P.:	n_{Da}
10.5^{20} (79)	1950°C (79)	.54 (79)

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

Solubility:
i. alkaline solvents, hot and cold H_2O; s. HNO_3, hot H_2SO_4, KCN (79).

Flammability:
Fine powder spontaneously flammable (148).

ALUMINUM

Mol. Wt.:	Formula:	
26.9815 (79)	Al	
M.P.:	Characteristics	
659.7°C (79)	Solid - silver colored powder, metallic, ductile (79)	
d./sp. gr.:	B.P.:	V.P.:
2.702 g/cm^3 (195)	2056°C (195)	1^{1284} (195)

Toxicity:
Low, possible cause of pulmonary fibrosis (195).

Synthesis:
From purified and calcined Al_2O_3 (obtained from bauxite). It is dissolved in molten cryolite ($2AlF_3 \cdot 6NaF \cdot 3CaF_2$) 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 temperature:
(80% pass through 270 mesh): 645°C (224).

Solubility:
i. cold and hot H_2O, concentrated HNO_3, hot CH_3COOH; s. alkaline solvents, HCl, H_2SO_4 (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/ft^2/(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 HNO_3, or nitrosyl fluoride (143).

Solubility:

i. cold and hot H_2O; v. sl. s. HNO_3 (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.:
3.51^{20} (79)

B.P.:
1527°C (79)
1140°C (195)

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

Synthesis:
(1) $3BaO + 2Al \rightarrow 3Ba + Al_2O_3$ (repeat distillation in high vacuum) (80)
(2) $Ba(N_3)_2 \rightarrow Ba + 3N_2$ (decomposition) (80)

Solubility:
d. with evolution of H_2 in H_2O; s. alcohol; i. C_6H_6 (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.:
1.348^{20} (79)

B.P.:
2970^{760} (79)

Toxicity:
Extremely toxic respiratory poison and eye irritant; threshold limit value .002 mg/m^3 (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 H_2O, Hg; s. dilute acid, alkaline solvent; sl. s. with d. hot H_2O (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.:
$\frac{1}{1021}$ (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 HNO_3 (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 (195).

CALCIUM

Mol. Wt.:
40.08

Formula:
Ca

M.P.:
848 ± .5°C (79)

B.P.:
1240°C (79)

V.P.:
$10^{9.85}$ (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 ($3CaO + 2\ Al \rightarrow Al_2O_3 + 3Ca$)
(3) reduction of lime with silicon ($8\ CaO + 2Si \rightarrow (2CaO.SiO_2) + 4Ca$)
} (132)

Unique conditions, reaction products:
Yields hydrogen on contact with H_2O (195).

Solubility:
d. in H_2O to yield H_2 + $Ca(OH)_2$; 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.:
1 at 394 (195)

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

n_D:
.82 (mμ) (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 H_2O; s. acid, NH_4NO_3, hot H_2SO_4 (79)

Thermodynamic properties:
latent heat of fusion: 13.2 cal/g
latent heat of vaporization: 286.4 cal/g
electrical resistivity: 34.12μ 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:
$2CeCl_3 + 3Ca \rightarrow 2Ce + 3CaCl_2$ (80)

Solubility:
sl. d. cold H_2O; d. hot H_2O; s. dilute acid; i. alkaline solvent (79)

Military and industrial uses:
Used in: magnesium and aluminum alloys to impove 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) $2CoO(OH) + 3H_2 \rightarrow 2Co + 4H_2O$ (reduce cobalt (III) hydroxide in porcelain boat and reduce in stream of hydrogen) (80)
(2) Add 200 ml 20% NaOH to $Al(NO_3)_3 \cdot 9H_2O$ in 300 ml H_2O, redissolve the precipitate and add a 500 ml H_2O solution of 29.1g $Co(NO_3)_3 \cdot 6H_2O$ and 20 ml concentrated HNO_3; settle, wash with H_2O, centrifuge, and dry the violet rose precipitate; grind under H_2O and boil until nitrate is absent, centrifuge and dry (80).

Unique conditions, reaction products:
Incandescent with acetylene (143).

Solubility:
i. cold and hot H_2O; 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±10°C (79)

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

d./sp. gr.: 7.20^{28} (79)

B.P.: 2480°C (79)

V.P.: 1^{1616} (79)

Synthesis:

(1) $Cr_2O_3 + 2Al \rightarrow 2Cr + Al_2O_3$ (80)

(2) $2K_2[CrCl_5(H_2O)]_4 + 3Mg \rightarrow 2Cr + 3MgCl_2 + 4KCl + 2H_2O$ (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: Cs

M.P.: 28.6°C (79)

Characteristics: Solid - silver metallic hexagonal crystal (79)

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

B.P.: 670±5°C (79)

V.P.: 1^{279} (195)

Toxicity:

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

Synthesis:

$2\ Cs_2CrO_4 + Zr \rightarrow 4Cs + Zr(CrO_4)_2$ (80)

Unique conditions, reaction products:

Combines vigorously with halides at room temperature (30); with H_2O or steam yields heat and hydrogen (195); possible vigorous reaction with oxidizing material (195).

Solubility:
d. cold H_2O; s. liquid NH_3 (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.:	Formula:	
63.54	Cu	
M.P.:	**Characteristics:**	
1083°C (79)	Solid - red metal, cubic (79)	
d./sp. gr.:	**B.Pt.**	**V.P.:**
8.92 (79)	2595°C (79) 2324°C (195)	11628 (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 H_2O; s. HNO_3, hot H_2SO_4; v. sl. s. HCl, NH_4OH (79).

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

Flammability:
Fine powders spontaneously flammable (148).

DEUTERIUM

Mol. Wt.:
4.032

Formula:
D_2

Synonyms:
Heavy hydrogen

M.P.:
-254.6[121] (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.:	Formula:	Synonyms:
55.847	Fe	Ferrum
M.P.:	Characteristics:	
1535°C (195)	Solid - silver cubic metal (79)	
d./sp. gr.:	B.P.:	V.P.:
7.86 (79)	3000°C (195)	1^{1787} (195)

Toxicity:
Nil, except very low on inhalation; threshold limit 15 mg/m^3 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/m^3; fresh iron oxide fumes can cause metal fume fever (195).

Synthesis:
$2Fe(OH)_3 \xrightarrow[3H_2]{\Delta} 2Fe + 6H_2O$ (80).

Unique conditions, reaction products:
Incandescent reaction with ClF_3 (143).

Ignition temperature:
(99 through 270 mesh): 320°C (224).

Solubility:
i. hot and cold H_2O; 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.:	Formula:
178.49	Hf
M.P.:	Characteristics:
2330°C (79)	Solid - hexagonal (79)
d./sp. gr.:	B.P.:
13.31 (79)	> 3200°C (79)

Synthesis
Thermal decomposition of its iodide, reduction of the tetrachloride or of the hydrofluorohafnide 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 H_2O (79)

Flammability:
Spontaneously flammable (213)

POTASSIUM

Mol. Wt.:	Formula:	Synonyms:
39.102	K	Kallium
M.P.:	Characteristics:	
62.3°C (79)	Solid - silver cubic metal (79)	
d./sp. gr.:	B.P.:	V.P.:
$.86^{20}$ (79)	760°C (79)	1^{341} (195)

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

Synthesis
$KN_3 \rightarrow K + 3/2N_2$ (80)

Unique conditions, reaction products:
Yields $KOH + H_2$ in reaction with H_2O; potassium melts and spatters and releases sufficient heat to ignite H_2 released, if confined may have explosion; potassium metal will form K_2O_2 and KO_2 or K_2O_4 at room temperature even if stored under mineral oil; may explode if handled or cut (195); ignites spontaneously in dry Cl, F and NO_2, is incandescent with CHO_3 and Na_2O_2 (142).

Solubility:
d. to KOH in hot or cold H_2O; d. alcohol; s. acid, Hg, NH_3 (79).

Handling:
Store in inert atmosphere or under O_2 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.:
$.534^{20}$ (79)

B.P.:
1317°C (79)

V.P.:
1^{723} (79)

Toxicity:

Slight, very caustic in H_2O (195).

Synthesis:

(1) LiBr $\xrightarrow{\text{electric arc}}$ Li + 1/2 Br_2 (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 H_2O (79); dissolves (with evolution of H_2) in dilute HCl or H_2SO_4 (132); s. liquid NH_3 (132).

Handling:

Protect from physical damage; avoid H_2O, high temperatures and halogenated hydrocarbons (142); immerse in inert O_2 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: 45.25μ 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 phosphoiodide and explodes with chloroform or methyl chloride(143).

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

Solubility:
i. cold H_2O, CrO_2, alkaline solvents; d. to $Mg(OH)_2$ in hot H_2O; 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

Mol. Wt.:
54.93

Formula:
Mn

M.P.:
1212°C (79)

Characteristics:
Solid - grayish pink cubic or tetragonal metal (79)

d./sp. gr.:
7.44 (79)

B.P.:
2152°C (79)

V.P.:
$\frac{1}{1282}$ (79)

Toxicity:
Maximum allowable concentration is 5 mg/m^3, high chronic systemic on inhalation; moderate acute systemic on inhalation (195).

Synthesis:
Electrolyze $MnSO_4 \cdot 4H_2O + (NH_4)_2SO_4$ distill manganese prepared in this fashion, place in Al_2O_3 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 H_2O (cold) (80).

Unique conditions, reaction products:
Powdered manganese ignites and burns brilliantly in Cl, incandesces with F, incandesces and feebly explodes with HNO_3, ignites in NO_2 (143).

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

Solubility:
d. cold and hot H_2O; 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

Mol. Wt.:
95.94

Formula:
Mo

M.P.:
2620 ± 10°C (79)

Characteristics:
Solid - silvery white metal to grayish black cubic powder (79)

d./sp. gr.:
10.2 (79)

B.P.:
$\frac{4057^{760}}{}$ (79)

V.P.:
$\frac{1^{3102}}{}$ (195)

Synthesis:

(1) $MoO_3 + 3H_2 \rightarrow Mo + 3H_2O$ (80)

(2) $3MoO_2 + 4Al \rightarrow 3Mo + 2Al_2O_3$ (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.:
$.97^{20}$ (79)

B.P.:
883°C (79)

V.P.:
1.2^{400} (195)

n_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) $2Na_2MoO_4 + Zr \rightarrow 4Na + Zr(MoO_4)_2$ (80)

(2) $2Na_2WO_4 + Zr \rightarrow 4Na + Zr(WO_4)_2$ (80)

(3) $NaN_3 \rightarrow Na + 3/2N_2$ (80)

(4) electrolytic production from fused NaCl (190)

Ignition temperature:

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

Solubility:

d. cold H_2O to yield $NaOH + H_2$; 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 H_2O 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)
2900°C (195)
3177°C (80)

V.P.:
1^{1510} (195)

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

Synthesis
(1) $NiO + H_2 \rightarrow Ni + H_2O$ (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 H_2O, NH_3; s. dilute HNO_3; sl. s. HCl, H_2SO_4 (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)

Characteristics
Solid - yellow to white cubic or wax like (79)

$n_D^{\ }$
$\frac{}{2.144}$ (79)

d./sp. gr.:
1.82^{20} (79)

B.P.:
280°C (79)

V.P.:
$\frac{}{1^{76.6}}$ (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 CO_2 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:

$.000315^{15}$ H_2O; sl. s. hot H_2O; 3 alcohol; 880^{10} CS_2; s. C_6H_6, NH_3, alkaline solns, ether, chlorine, $C_6H_5CH_3$ (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

M.P.:
590[43] (79)

Characteristics:
Solid - reddish brown cubic or amorphous powder (79)

d./sp. gr.: 2.34
2.34 (79)

B.P.:
Ignites 200°C (79)

V.D.:
4.77 g/cm^3 (195)

Toxicity:
Slight as irritant, moderate on injestion (195).

Synthesis:
Formed from white phosphorus at 240°C in absence of O_2 (214).

Unique conditions, reaction products:
Explosive when mixed with oxidizing materials (193).

Ignition temperature:
Autoignition temperature 500°F (195).

Solubility:
v. sl. s. cold H_2O; i. hot H_2O, CS_2, alcohol, NH_3; 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 $Y = 2X = [K(T_o - T_a)/Q]^{1/2}$ 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 gineration of heat which is directly proportional to the oxidation rate of red phosphorus (212).

LEAD

Mol. Wt.:
207.19

Formula:
Pb

M.P.:
327.43°C (79)

Characteristics:
Solid - silvery bluish white soft cubic metal (79)

d./sp. gr.:
11.288[20] (79)

B.P.:
1515°C (79)

V.P.:
1[973] (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 H_2O; s. HNO_3, hot concentrated H_2SO_4 (79)

Thermodynamic properties:
latent heat of fusion: 8.89 cal/g
latent heat of vaporization: 204.6 cal/g
electrical resistivity: 24.6 μ ohms (at 327°C) } (121)
surface tension: 442 dynes/cm (at 350°C)

Flammability:
Spontaneously flammable (115)

PLUTONIUM

Mol. Wt.:	Formula:
242.00	Pu

M.P.:	B.P.:
639.5 ±2°C (79)	3235 ± 19°C (79)

Toxicity:
Highly toxic. (195).

Synthesis:
Obtained by neutron bombardment of U^{238} (57)

Military and industrial uses:
Nuclear-reactor fuel and product (57).

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

RUBIDIUM

Mol. Wt.:	Formula:
85.47	Rb

M.P.:	Characteristics
38.5°C (79)	Solid - silver white soft metal (79)

d./sp. gr.:	B.P.:	V.P.:
1.532 (sol) (79)	700°C (79)	1^{297} (195)
$1.475^{38.5}$ (liq) (79)		

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

Synthesis

(1) $2Rb_2CrO_4 + Zr \rightarrow 4Rb + Zr(CrO_4)_2$
(2) $2Rb_2Cr_2O_7 + Zr \rightarrow 4Rb + Zr(Cr_2O_7)_2$ } (80)
(3) $RbCl + 1/2Ca \rightarrow 1/2\ CaCl_2 + Rb$

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 μ ohm/in.
ionization potential: 4.126 volts
thermal conductivity (liq): 11.65 Btu/hr ft°F
thermal conductivity (vap): .00482 Btu/hr ft°F } (216)
specific heat (liq): .0877 Btu/lb°F
specific heat (vap): .0578 Btu/lb°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

M.P.:
α 95.5-112.8°C (79)
β 118.75°C (79)
γ about 120°C (79)

d./sp/ gr.:
α 2.07^{20} (79)
β 1.96 (79)
γ 1.92 (79)

Formula:
S_8

Characteristics:
α Solid - yellow rhombic (79)
β Solid - pale yellow monoclinic (79)
γ Solid - pale yellow amorphous

B.P.:
α, β, γ } 444.6°C (79)

n_D
α 1.957 (79)

Synonyms:
Sulfur flour
Flowers of sulfur
Brimstone

V.P.:
$1^{183.8}$ (195)

Toxicity:
Very low (195).

Synthesis
Purify commercial sulfur by repeated recrystallation 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
α 23°CS_2; sl. s. $C_6H_5CH_3$, alcohol, C_6H_6, ether, liquid NH_3; s. CCl_4 } (79)
β 70°CS_2; s. alcohol, C_6H_6
γ i. CS_2

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.:
$\frac{1}{11724}$ (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.:
1^{1492} (195)

$^{n}D_{t}$
(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; Na_2O_2 oxidizes tin to incandescence (143).

Solubility:
i. hot and cold H_2O; s. HCl, H_2SO_4, aqua regia, alkaline solvents; sl. s. HNO_3 (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.:
2.6^{20} (79)

B.P.:
1366°C (79)

V.P.:
10892 (79)

Synthesis:
$Sr(N_3)_2 \rightarrow Sr + 3N_2$ (80)

Solubility:
s. liquid NH_3, HNO_3, HCl, dilute H_2SO_4 (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/m^3 (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±1°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/m^3 air (soluble uranium compounds); .25 mg/m^3 air (insoluble uranium compounds) (195).

Synthesis:
(1) $UO_2 + 2Ca \rightarrow U + 2CaO$ (metallic calcium reduces oxide) (80)
(2) Reduce U_3O_8 by freshly distilled calcium in high vacuum (yields very pure uranium) (80)
[$CaCl_2 + BaCl_2$ (prefused) added to reactant mixture above improves procedure] (80)
(3) $UCl_4 + 4Na \rightarrow U + 4NaCl$ (80)
(4) $UCl_5 + 5Na \rightarrow U + 5NaCl$ (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.:
19.35^{20}_{4} (79)

B.P.:
5900^{760} (79)

V.P.:
1^{3990} (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/°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.:
907^{760} (79)

V.P.:
1^{487} (195)

Toxicity:
When heated it evolves fumes which cause "brass founders ague" (195); threshold limit of fumes 15 mg/m^3 (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 (242)

Solubility:
i. hot and cold H_2O; 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, flares (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/m^3 air; low for acute and chronic exposures (195).

Synthesis:
(1) $ZrI_4 \rightarrow Zr + 2I_2$
(2) $ZrO_2 + 2Ca \rightarrow Zr + 2CaO$
(3) $K_2ZrF_6 + 4Na \rightarrow Zr + 2KF + 4NaF$ (80)
(4) $ZrCl_4 + 4Na \rightarrow Zr + 4NaCl$
(5) $ZrCl_4 + 2Mg \rightarrow Zr + 2MgCl_2$

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 H_2O; s. HF, aqua regia; sl. s. CH_3COOH (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.:	Formulas:
$CeHg_4$ 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.:	Formulas:
Ce_2In 395.06	Ce_2In
CeIn 254.94	CeIn (235)
Ce_2In_3 624.70	Ce_2In_3

Unique conditions, reaction products:
$CeIn_3$ not pyrophoric (235)

Military and industrial uses:
Spontaneously flammable alloys, 0%-30% Ce alloy has the greatest pyrophoricity (235).

CERIUM HYDRIDE AMALGAM

Formula:
$(CeH_2)_x(Hg)_y$

Flammability:
Concentrated mixtures of CeH_3 and Hg on admission to air rapidly develop a luminous black precipitate and ignite spontaneously, black precipitate reasonably pure CeH_3; CeH_3 amalgam broken under water results in a vigorous reaction evolving H_2 and sparks (215).

COBALT AMALGAM

Formula:
$(Co)_x(Hg)_y$

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 (159); (2) react sodium amalgam and concentrated solution of cobalt chlorides (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. H_2O; i. Hg (131).

Flammability:

Spontaneously flammable (169).

CHROMIUM-COBALT ALLOY

Formula:

$(Cr)_x(Co)_y$

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: Cs_3As

Flammability:

Spontaneously flammable (240).

CESIUM BISMUTH ALLOY

Mol. Wt.: 682.64

Formula: Cs_3Bi

Flammability:

Spontaneously flammable (240).

CESIUM-ANTIMONY ALLOY

Mol. Wt.:	Formula:
(Cs_3Sb) 595.41	Cs_3Sb
(Cs_5Sb_4) 487.04	Cs_5Sb_4

Flammability:
Spontaneously flammable (240).

IRON AMALGAM

Formula:
$(Fe)_x(Hg)_y$

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

Formula:
$(K)_x(As)_y$

Flammability:
Spontaneously flammable (240).

POTASSIUM-PHOSPHORUS ALLOY

Mol. Wt.:	Formula:
148.27	K_3P

Flammability:
Spontaneously flammable (240).

POTASSIUM-ANTIMONY ALLOY

Mol. Wt.:	Formula:
(K_3Sb) 239.06	K_3Sb
(K_5Sb_4) 682.54	K_5Sb_4

Thermodynamic properties:
heat of formation (K_3Sb): -17850 ±2000 cal/g atom (at 298°K) (87).

Flammability:

Spontaneously flammable (240).

LANTHIUM-ANTIMONY ALLOY

Mol. Wt.:

(La_2Sb) 369.60
($LaSb$) 259.68
($LaSb_2$) 382.44

Formulas:

La_2Sb
$LaSb$
$LaSb_2$ } (235)

Flammability:

Spontaneously flammable (235).

LITHIUM PHOSPHORUS ALLOY

Mol. Wt.:

37.91

Formulas:

LiP

Flammability:

Spontaneously flammable (240).

MANGANESE-BISMUTH ALLOY

Mol. Wt.:

263.93

Formulas:

MnBi

Synthesis

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

Flammability:

Spontaneously flammable (240).

SODIUM AMALGAM

Mol. Wt.:

(Hg_3Na) 624.82
(Hg_8Na_7) 1765.81
(Hg_2Na_5) 516.17
(Hg_4Na) 825.43
(Hg_2Na) 424.21
($HgNa$) 223.60
(Hg_2Na_3) 470.19

Formulas:

Hg_3Na, Hg_8Na_7, Hg_2Na_5, Hg_2Na_3, Hg_4Na, Hg_2Na, $HgNa$, Hg_2Na_5 (85)

Characteristics

Hg_2Na Solid-hexagonal c-32 ordered structure
$HgNa$ Solid-orthogonal crystal
Hg_2Na_3 Solid tetragonal crystal
Hg_2Na_5 Solid rhombic crystal
Hg_4Na 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 (60)); (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:
$(Na)_x(K)_y$ (40-90%K)

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
%Na Gibbs free energy
40% 245 cal/g atom
60% 245 cal/g atom
80% 190 cal/g atom
90% 135 cal/g atom
} (36)

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 motor currents (198).

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

SODIUM LEAD ALLOY

Mol. Wt.:
$(Na_{15}Pb_4)$ 1173.69
(Na_4Pb_2) 529.37
(Na_9Pb_4) 1035.75
$(NaPb)$ 230.20
} (88)

Formula:
$(Na)_x(Pb)_y$

Thermodynamic properties

xPb	Gibbs free energy	Enthalpy	Entropy	
.2 ($Na_{15}Pb_4$)	-3800 cal/g atom	-400 cal/g atom	-.7 cal/°Kg atom	(88)
.286 (Na_5Pb_2)	-4900 cal/g atom	-5000 cal/g atom	-.4 cal/°Kg atom	
.306 (Na_9Pb_4)	-5000 cal/g atom	-5200 cal/g atom	-.7 cal/°Kg atom	
.50 (NaPb)	-5350 cal/g atom	-5800 cal/g atom	-1.5 cal/°Kg atom	
.70 (β)	-3450 cal/g atom (±400)	-3300 cal/g atom (±500)	-.6 cal/°Kg atom (±1.0)	

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

NICKEL-IRON ALLOY

Formula:
$(Ni)_x(Fe)_y$
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 LANTHUM

Mol. Wt.:
256.34

Formula:
Ni_2La (239)

Flammability:
Spontaneously flammable (238)

RUBIDIUM-ARSENIC ALLOY

Mol. Wt.:
331.36

Formula:
Rb_3As (240)

Flammability:
Spontaneously flammable (240)

RUBIDIUM-BISMUTH ALLOY

Formula:
Rb_3Bi (240)

Flammability:
Spontaneously flammable (240).

RUBIDIUM-ANTIMONY ALLOY

Mol. Wt.:	Formulas:
(Rb_3Sb) 378.20	Rb_3Sb (240)
(Rb_5Sb_4) 487.04	Rb_5Sb_4

Flammability:
Spontaneously flammable (240).

THORIUM SILVER ALLOY

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

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

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.:	Formulas:
(UBi) 447.06	UBi
(U_3Bi_4) 1342.17	U_3Bi_4 (240)
(UBi_2) 656.05	UBi_2

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

(c) AMIDES, IMIDES

CADMIUM AMIDE

Mol. Wt.:
144.45

Formula:
$Cd(NH_2)_2$

M.P.:
d. 120°C (79)

d./sp. gr.:
3.05^{25} (79)

Synthesis
$Cd(SCN)_2 + 2KNH_2 \rightarrow Cd(NH_2)_2 + 2KSCN$ (80)

Flammability:
Spontaneous heating and possible explosion with H_2O (143).

CESIUM AMIDE

Mol. Wt.:
148.93

Formula:
$CsNH_2$

M.P.:
262 ± 1°C (79)

Characteristics
Solid - white needles (79)

d./sp. gr.:
3.44_4^{25} (79)

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

Solubility:
d. cold H_2O; s. liquid NH_3 (75)

Thermodynamic properties
standard heat of formation -25.4 kcal/mol (79)

Flammability:
Incandescent in air (143).

LITHIUM AMIDE

Mol. Wt.:
22.96

Formula:
$LiNH_2$

M.P.:
380°-400°C (132)

Characteristics:
Solid - colorless cubic needles (79)

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

Synthesis:
$Li + NH_3 \rightarrow LiNH_2 + 1/2H_2$ (132)

Unique conditions, reaction products:
Sublimes in NH_3 current (132); $LiNH_2 + H_2O \rightarrow LiOH + NH_3$ (132).

Solubility:
s. cold H_2O; d. hot H_2O; sl. s. liquid NH_3, alcohol; i. ether, C_6H_6 (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:
$LiN(CH_3)_2$

Characteristics:
Solid - white (53)

Flammability:
Spontaneously flammable (53)

MAGNESIUM DIAMIDE

Mol. Wt.:
56.36

Formula:
$Mg(NH_2)_2$

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 $Mg(C_2H_5)_2$ or (2) on Mg activated with I_2 at 400°C (132).

Unique conditions, reaction products:
Violent reaction with water to yield ammonia gas (195).

Solubility:
d. cold H_2O alcohol; v. sl. s. liquid NH_3 (79).

Flammability:
Spontaneously flammable in air (195).

SODIUM AMIDE

Mol. Wt.:	Formula:	Synonyms
39.01	$Na(NH_2)$	Sodamide

M.P.:
210°C (79)

Characteristics
Solid - white (79)

B.P.:
400°C (79)

Synthesis
$Na + NH_3 \xrightarrow{300°C} NaNH_2 + 1/2H_2$ (80)

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 H_2O, hot alcohol; . l liquid NH_3 (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.:	Formula:
222.21	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. [$BaCO_3 + 3Mg + C \rightarrow 3MgO + BaC_2$] (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)

$\frac{n_D}{}$:
> 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) $CaO + 3C \rightarrow CaC_2 + CO$
(3) $CaCN_2 \rightarrow CaC_2 + 2N_2 + Ca$ } (80)
(4) $CaCN_2 + C \rightarrow CaC_2 + N_2$

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.:
KC_8 135.1
KC_{24} 327.1

Formulas:
KC_8
KC_{24}

Characteristics:
KC_8 Solid-dark copper red to bronze
KC_{24} 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

Formulas:
KHC_2

d./sp. gr.:
1.37 (79)

Characteristics:
Solid - colorless rhombic crystals (79)

Unique conditions, reaction products:
Explosive reaction with H_2O (143).

SODIUM CARBIDE

Mol. Wt.:
70.00

Formulas:
Na_2C_2

M.P.:
About 700°C (79)

Characteristics:
Solid - white powder (79)

d./sp. gr.:
1.57^{15} (79)

Synthesis:
$2Na + 2C_2H_2 \rightarrow 2NaHC_2 + H_2$; $2NaHC_2 \rightarrow Na_2C_2 + C_2H_2$ (80)

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 [$TiO_2 + 2C \rightarrow TiC + CO_2$] (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

$UO_2 + C \xrightarrow[900°C]{\text{vacuum}} UC$ (heat mixture of UO_2 + C to glowing) (240).

Unique conditions, reaction products

Reactive with water (193).

Thermodynamic properties

Thermal conductivity: .06 cal/sec/cm/°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 40μ very pyrophoric (240).

URANIUM CARBIDE

Mol. Wt.:	Formula:
262.05	UC_2
M.P.:	Characteristics
2350°-2400°C (79)	Solid - metallic crystal (79)
d./sp. gr.:	B.P.:
11.28^{16} (79)	4370^{760} (79)

Solubility:

d. cold and hot H_2O, dilute inorganic acids; i. alcohol (79)

Flammability:

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

ZIRCONIUM CARBIDE

Mol. Wt.:	Formula:	
103.23	ZrC	
M.P.:	Characteristics	
3540°C (190)	Solid - gray cubic metal (79)	
d./sp. gr.:	B.P.:	Hardness
6.78 (190)	5100°C (190)	.84 mohrs (190)

Synthesis

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

Solubility:
i. H_2O, 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.:	Formula:
195.90	$Fe(CO)_5$
M.P.:	**Characteristics**
-21°C (79)	Liquid - viscous yellow (79)
d./sp. gr.:	**B.P.:**
1.457^{21} (79)	102.8^{749} (79)

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

Synthesis:
$Fe + 5CO \xrightarrow[\Delta]{\text{pressure}} Fe(CO)_5$ (80)

Ignition temperature:
flash point 5°F (195)

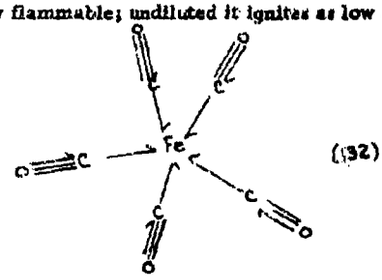
Solubility:
i. cold H_2O; s. alcohol, ether, C_6H_6, alkaline solvents, concentrated H_2SO_4 (79)

Thermodynamic properties
dipole moment .64-.81
heat of formation (at 18°C): -189.5 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:



(132)

POTASSIUM CARBONYL

Mol. Wt.:	Formula:
402.68	$(KCO)_6$

M.P.:
Explodes (79)

Characteristics
Gray-red (79)

B.P.:
d. 250°C (103)

Toxicity:
Highly toxic (195)

Solubility:
Explodes with cold H_2O; d. alcohol (79).

Synthesis:
Pass dry purified CO into a solution of potassammonium 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, H_2O 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 H_2O (143).

Synthesis
Pass pure dry CO into solution of sodammonium in liquified ammonia at about -50°C, blue color becomes lilac tinged, 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.:
1.32^{17} (79)

B.P.:
43°C (79)

V.P.:
$400^{25.8}$ (135)

Toxicity:

High on inhalation (local and systemic); slight allergen: high on inhalation (chronic systemic); Tolerance level ACGIH .001 ppm (.007 mg/m^3) (195).

Synthesis:

$NiSO_4 + Na_2S_2O_4 + (x + 2)NH_3 + H_2 \rightarrow NiSO_2 \cdot (NH_3)_x + Na_2SO_4 + (NH_4)_2SO_3$; $NiSO_2 \cdot (NH_3)_x + H_2O + CO \rightarrow Ni(CO)_4 + (NH_4)_2SO_3 + (x - 2)NH_3$ (80)

Solubility:

s. aqua regia, alcohol, ether, C_6H_6, HNO_3; i. dilute acid, dilute alkaline solvent (79).

Flammability:

In the presence of air, $Ni(CO)_4$ forms a deposit which becomes peroxided, this tends to decompose and ignite (143).

DIVANADIUM DODECACARBONYL

Mol. Wt.:
438.02

Formula:
$V_2(CO)_{12}$

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. CS_2 (175).

Flammability:

Spontaneously flammable (175).

(f) HALIDES

ARSENIC TRICHLORIDE

Mol. Wt.:	Formula:
181.28	$AsCl_3$

M.P.:	Characteristics
-8.5°C (79)	Liquid - oily (190)

d./sp. gr.:	B.P.:	$n_D^{14°F}$
2.163^{20} (79)	63^{752} (79)	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, PCl_3, alcohol, ether; d. hot and cold H_2O (79).

Thermodynamic properties

	Gas	Liquid	
standard heat of formation:	-71.5 kcal/mol	-80.2 kcal/mol	(79)
standard free energy of formation:	-62.5 kcal/mol	-70.5 kcal/mol	
entropy (at 25°C):	78.2 e.u.	55.5 e.u.	

Military and industrial uses
Used in poison gas and ceramics (190).

BORON ARSENOTRIBROMIDE

Mol. Wt.:	Formula:
328.47	BBr_3AsBr_3

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

BORON TRIBROMIDE

Mol. Wt.:	Formula:
250.54	$B(Br)_3$

M.P.:	Characteristics
-46°C (79)	Liquid - colorless fuming

d./sp. gr.:	B.P.:	χ_D:
2.6431$^{18.4}_{4}$ (79)	91.3 ± .25°C (79)	16.3 (79)

Synthesis

(1) $AlBr_3 + BF_3 \rightarrow BBr_3 + AlF_3$ (80)
(2) $B + 1/2Br_2 \rightarrow BBr_3$

Unique conditions, reaction products

Explodes with H_2O (143).

Solubility:

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

Thermodynamic properties

	Solid	Liquid	
standard heat of formation:	-44.6 kcal/mol	-52.8 kcal/mol	(79)
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.:	Formula:	
163.47	B_2Cl_4	
M.P.:	**Characteristics**	**B.P.:**
-91°C (226)	Liquid colorless (226)	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
heat of vaporization (at 220°K): 8670 ± 70 cal/mol (155)
entropy (at 1 atmosphere and 220°K): 80.27 e.u.

Flammability:

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

MONOCHLORODIBORANE

Mol. Wt.:	Formula:	
62.14	$H_5B_2H_2Cl$	
M.P.:	**Characteristics**	**B.P.:**
-112°C (226)	Gas - colorless (226)	0°C (226)

Solubility:
s. organic solvents; d. H_2O, air (226).

Flammability:
Spontaneously flammable (226).

BORON CHLORIDE TETRAMER

Mol. Wt.:
185.12

Formula:
$(BCl)_4$

M.P.:
d. 75°C (225)

Characteristics:
Solid - yellow crystals (226)

V.P.:
$23^{1.5}$
68^{34} (226)

Flammability:
Spontaneously flammable (226).

BISMUTH PENTAFLUORIDE

Mol. Wt.:
304.00

Formula:
BiF_5

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:
$BiF_3 + F_2 \rightarrow BiF_5$ (80)

Unique conditions, reaction products:
Reacts violently with water and petrolatum (195).

Flammability:
Reacts with H_2O sometimes with ignition (80).

BROMINE PENTAFLUORIDE

Mol. Wt.:
174.90

Formula:
BrF_5

M.P.:
-61.3°C (79)

Characteristics:
Liquid - colorless (79)

V.P.:
7 psia (at 70°F) (190)

d./sp. gr.:
2.57^0 (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 H_2O; fumes strongly in air (80).

Solubility:
d. hot and cold H_2O (79)

Military and industrial uses:
Oxidizer in liquid rocket propellants (190).

CALCIUM HYPOCHLORITE
(With > 39% available chlorine)

Mol. Wt.:	Formula:
91.53	CaOCl

Unique conditions, reaction products:
Decomposes in H_2O; with heat or sun may decompose, spontaneously rupturing container; vapors evolved may ignite spontaneously in air (54).

CHLORINE TRIFLUORIDE

Mol. Wt.:	Formula:	
92.45	ClF_3	
M.P.:	Characteristics:	V.d.:
-83°C (79)	Gas - colorless, sweet odor (79)	3.14 (79)
F.P. -105°C (150)		
	B.P.:	Viscosity (liq): (1)
d./sp. gr.:	11.3°C (79)	.438 cp (at 67°F)
1.77^{13} (79)		

Toxicity:
Emits highly toxic fumes with H_2O, -COOH, or acid fumes (195); strongly attacks bronchi (80); MAC (Maximum acceptable concentration) .1 ppm (1).

Synthesis:
$$Cl_2 + 3F_2 \xrightarrow[Ni]{270\text{-}280^\circ C} 2ClF_3 \quad (80)$$

Unique conditions, reaction products:
Ignites on contact with many organic compounds, reacts violently with oxidizable materials (195); reacts violently with H_2O (62).

Solubility:
d. cold and hot H_2O (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

Mol. Wt.:	Formula:	Synonyms:
154.90	CrO_2Cl_2	Chromium oxychloride
M.P.:	**Characteristics**	**V.P.:**
-96.5°C (79)	Liquid -dark red (79)	20^{20} (195)
d./sp. gr.:	**B.P.:**	
1.911 (79)	117°C (79)	

Synthesis:

(1) $K_2CrO_4 + 2NaCl + 2H_2SO_4 \rightarrow CrO_2Cl_2 + Na_2SO_4 + K_2SO_4 + 2H_2$
(2) $K_2Cr_2O_7 + 4NaCl + 3H_2SO_4 \rightarrow 2CrO_2Cl_2 + K_2SO_4 + 2Na_2SO_4 + 3H_2O$ } (80)
(3) $CrO_3 + 2HCl \rightarrow CrO_2Cl_2 + H_2O$

Unique conditions, reaction products:

Forms a smoke with atmospheric moisture (80).

Solubility:

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

Thermodynamic properties:

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

LITHIUM HYPOCHLORITE
(With > 39% available chlorine)

Mol. Wt.:	Formula:
58.39	LiOCl

Characteristics
solid - white powder (54)

Unique conditions, reaction products
Decomposes in H_2O; with heat or sun may decompose spontaneously rupturing containers, the vapors evolved may ignite spontaneously in air (54).

SODIUM HYPOCHLORITE

Mol. Wt.:	Formula:
74.45	NaOCl
M.P.:	B.P.:
d. (195)	d. (195)

Synthesis
$2NaOH + Cl_2 + 4H_2O \rightarrow NaClO \cdot 5H_2O + NaCl$ (80)

Unique conditions, reaction products:
Decomposes explosively in air due to CO_2 (80).

Thermodynamic properties
standard heat of formations -82.7 kcal/mol (79).

PHOSPHORUS TRICHLORIDE

Mol. Wt.:	Formula:	
137.33	PCl_3	
M.P.:	Characteristics	V.P.:
-112°C (79)	Liquid - colorless fuming (79)	100^{21} (195)
d./sp. gr.:	B.P.:	V.d.:
5.4 (79)	75.5^{749} (79)	4.75 (195)
	n_D^{14}	
	1.516 (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 H_2O; s. ether, C_6H_6, chloroform, CS_2, CCl_4 (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 } (79)
standard entropy: 74.49 e.u.

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 PENTACHLORIDE

Mol. 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.:
$1^{55.5}$ (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

	gas	
standard heat of formation	-95.35 kcal/mol	(79)
free energy of formation (at 25°C)	-77.59 kcal/mol	
standard entropy	84.3 e.u.	

Military and industrial uses

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

PHOSPHORUS OXYCHLORIDE

Mol. Wt.:
153.33

Formula:
$POCl_3$

M.P.:
2°C (79)

Characteristics:
Liquid - colorless, fuming (79)

d./sp. gr.:
1.675 (79)

B.P.:
105.3°C (79)

^{n}D:
$1.460^{25.1}$ (79)

Unique conditions, reaction products:
Hydrolyzes violently with H_2O (217).

Solubility:
d. cold and hot H_2O, alcohol, acids (79)

Thermodynamic properties:

	gas	liquid
standard heat of formation:	-141.5 kcal/mol	
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 (132)
surface tension (at 25°C):		31.6 dynes/cm

TRIFLUORO PHOSPHANE SULFIDE

Mol. Wt.:
120.04

Formula:
$(S)PF_3$

M.P.:
-148.8°C (226)

Characteristics:
Gas (226)

B.P.:
d. -52.3°C (226)

Solubility:
d. H_2O; s. ether; i. organic solvents (226)

Flammability:
Spontaneously flammable (226).

SULFURYL CHLORIDE

Mol. Wt.:
134.97

Formula:
SO_2Cl_2

M.P.:
-54.1°C (79)

Characteristics:
Liquid - colorless (79)

d./sp. gr.:
1.667^{20}_{4} (79)

B.P.:
69.1°C (79)

^{n}D:
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) 2.7715^{25}_{4} (79)
(sol) 3.292^{-79} (79)

B.P.:
154°C (79)

V.d.:
2.82 (195)

Synthesis
$Si + 2Br_2 \rightarrow SiBr_4$ (80)

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) 1.483^{20} (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
$Si + 2Cl_2 \rightarrow SiCl_4$ (132)

Unique conditions, reaction products
Fumes heavily upon exposure to air (80).

Solubility:
d. hot and cold H_2O, alcohol (79)

Thermodynamic properties

	gas	liquid	
standard heat of formation	-145.7 kcal/mol	-153.0 kcal/mol	(79)
standard free energy of formation	-136.2 kcal/mol	-136.9 kcal/mol	
standard entropy	79.2 e.u.	37.2 e.u.	

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^{17}_{4} (195)

B.P.:
112°C (195)

V.P.:
8.8^{0} (195)

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

Synthesis
$Si + 3HBr \rightarrow SiHBr_3 + H_2$ (80)

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

M.P.:
-126.5°C (79)
-134°C (195)

d./sp. gr.:
1.34 (79)

Characteristics:
Liquid - colorless (79)

B.P.:
33^{758} (79)

n_D^{20}:
1.4020 (132)

n_D^{25}:
1.3983 (132)

Dipole moment:
.97 (132)

Viscosity:
.397 cp (at 0°C) (132)

V.d.:
4.7 (195)

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

Synthesis:
$Si + 3HCl \rightarrow SiHCl_3 + H_2$ (80)

Unique conditions, reaction products:
Violent reaction with water (27).

Ignition temperature:
flash point $< 20°F$ (195)

Solubility:
d. hot and cold H_2O; s. CS_2, CCl_4, chloroform, C_6H_6 (79)

Flammability:
Spontaneously flammable in air (195).

BROMO SILANE

Mol. Wt.:
111.02

M.P.:
-94°C (79)

d./sp. gr.:
1.72^{-80}
1.533^{0} (79)

Flammability:
Explodes in air (79)

Formulas:
SiH_3Br

Characteristics:
Gas - colorless (79)

B.P.:
1.9°C (79)

SILICON HEXACHLORIDE

Mol. Wt.:	Formula:	Synonyms:
268.89	Si_2Cl_6	Hexachlorodisilane
M.P.:	**Characteristics**	**V.d.:**
-1°C (79)	Liquid - colorless (79)	9.29 (195)
d./sp. gr.:	**B.P.:**	n_D^{18}:
1.58^{0} (79)	145^{768} (79)	1.4748 (79)

Synthesis

Pass vapor of silicon tetrachloride over white-hot silicon (contained in a porcelain tube), by cooling the products rapidly Si_2Cl_6 is separable by fractional distillation (131).

Solubility:

d. hot and cold H_2O, alcohol (79)

Flammability:

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

DISILYAMINO DICHLOROBORINE

Mol. Wt.:	Formula:	
157.93	$(SiH_3)_2NBCl_2$	
M.P.:	**Characteristics**	**V.P.:**
d. 62°C (226)	Solid (226)	25^{22} (226)

Flammability:

Spontaneously flammable (226).

ANTIMONY PENTACHLORIDE

Mol. Wt.:	Formula:	
299.02	$SbCl_5$	
M.P.:	**Characteristics**	**V.P.:**
2.8°C (79)	Liquid - white (79)	$1^{22.7}$ (195)
	Solid - monoclinic (79)	
d./sp. gr.:		n_D^{14}:
2.336_4^{20} (79)	**B.P.:**	
	79^{22} (79)	.601 (79)

Synthesis

Pass chlorine into molten $SbCl_3$ (132).

Unique conditions, reaction products

Gives white smoke with atmospheric moisture (167).

Solubility:
d. hot and cold H_2O; s. HCl, tartaric acid, methyl dichloride (79)

Thermodynamic properties:

	g	liquid	
standard heat of formation	-93.9 kcal/mol	-104.8 kcal/mol	(79)

TIN TETRACHLORIDE

Mol. Wt.:
260.50

Formula:
$SnCl_4$

M.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 [$SnCl_4 + 4H_2O \rightarrow Sn(OH)_4 + 4HCl$] (19).

Solubility:
s. cold H_2O, ether; d. hot H_2O (79)

Thermodynamic properties:

	Liquid	
standard heat of formation	-179.3 kcal/mol	(79)
standard free energy of formation	-161.2 kcal/mol	
standard entropy	60.4 e.u.	

TITANIUM DIBROMIDE

Mol. Wt.:
207.72

Formula:
$TiBr_2$

M.P.:
d. > 500°C (79)

Characteristics:
Solid - black powder (79)

d./sp. gr.:
4.31 (79)

Solubility:
s. cold H_2O with evolution of H_2 (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:
$TiCl_2$

Synonyms
Titanium (II) chloride

M.P.:
Sublimes H_2 (79)

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

d./sp. gr.:
3.13 (79)

B.P.:
d. 470 (in vacuum) (79)

Synthesis
$TiCl_4 + Ti \rightarrow 2TiCl_2$ (80)

Solubility:
d. cold H_2O; s. alcohol; i. ether, chloroform CS_2 (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 H_2O and dissolves with evolution of H_2 (131).

TITANIUM TRICHLORIDE
(Anhydrous)

Mol. Wt.:
154.26 (79)

Formula:
$TiCl_3$

M.P.:
d. 440°C (79)

Characteristics
Solid - dark violet deliquescent (79)

d./sp. gr.:
2.64 (79)

B.P.:
600-108 (79)

Synthesis
(1) $2TiCl4 + H_2 \rightarrow 2TiCl_3 + 2HCl$
(2) $3TiCl_4 + Ti \rightarrow 4TiCl_3$
(3) $3TiCl_4 + Sb \rightarrow 3TiCl_3 + SbCl_3$
(4) Reduce $TiCl_4$ with H_2 in an electric arc
} (80)

Solubility:
s. cold H_2O, hot H_2O; v. s. alcohol; s. HCl; i. ether (79)

Thermodynamic properties:

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

Military and industrial uses:
Used as reducing agent; in organic synthesis, as co-catalyst for polyolefin polymerization; in organometallic synthesis involving titanium (190).

Flammability:
Spontaneously flammable in air (124).

TITANIUM TETRACHLORIDE

Mol. Wt.:	Formula:	Synonyms:
189.71	$TiCl_4$	Titanic chloride
M.P.:	**Characteristics**	**V.P.:**
-25°C (79)	Liquid - light yellow (79)	$10^{21.3}$ (195)
d./sp. gr.:	**B.P.:**	$n^{10.5}$ D:
(liq) 1.726	136.4°C (79)	1.61 (79)
(sol) 2.06 [-79] (79)		

Toxicity:
High (acute local) as irritant, on inhalation; high (chronic local) on inhalation; can cause severe burns, do not wash with H_2O (severe burns due to formation of HCl) (195).

Synthesis:
$TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$ (80)

Unique conditions, reaction products:
Produces white fumes in moist air; liberates heat and HCl on contact with moisture (195); readily forms adducts with HN_3, pyridine and non metal chlorides (89).

Solubility:
s. cold H_2O; d. hot H_2O; 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 NH_3 vapor gives a denser smoke (19, 20).

TITANIUM DIIODIDE

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:

	crystalline	
standard heat of formation	-61 kcal/mol	(79)

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.:
1.82[9] (79)

B.P.:
126.7°C (79)

Synthesis:
(1) $V_2O_5 + 3SOCl_2 \rightarrow 2VOCl_3 + 3SO_2$ (80)
(2) $V_2O_3 + 3Cl_2 \rightarrow 2VOCl_3 + 1/2O_2$ (80)

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

	crystalline
standard heat of formation	-172 kcal/mol (79)

ZIRCONIUM DIBROMIDE

Mol. Wt.:	Formula:	Synonyms:
251.05	$Zr(Br)_2$	Dibromo zircine

M.P.:	Characteristics
d. 350°C (226)	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 H_2O (226)

Thermodynamic properties

	crystalline
standard heat of formation	-120 kcal/mol (79)

Flammability:
Spontaneously flammable (226).

(g) HYDRIDES

ALUMINUM BOROHYDRIDE

Mol. Wt.:
71.54

Formula:
$Al(BH_4)_3$

Synonyms:
Aluminum tris (tetrahydroborane)

M.P.:
71.54

Characteristics:
Liquid - colorless (226)

V.P.:
Log P = 7.808-1565/T; 12^{0}, 25^{17} (226)

d./sp. gr.:
$.561^{0}$, $.533^{10}$, $.544^{20}$, $.537^{29.4}$ (226)

B.P.:
44.5°C (226)

Synthesis:
(1) $(CH_3)_3Al + 2B_2H_6 \rightarrow (CH_3)_3B + Al(BH_4)_3$ (70)
(2) $2AlH_3 + 3B_2H_6 \rightarrow 2Al(BH_4)_3$ (70)
(3) $LiAlH_4 + 2B_2H_6 \rightarrow LiBH_4 + Al(BH_4)_3$ (70)

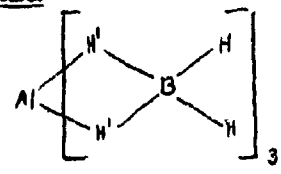
Unique conditions, reaction products:
Forms addition compounds readily with amines (226).

Solubility:
d. H_2O (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 = 2.15Å
Al - H' = 2.1Å
B - H' = 1.28Å
B - H = 1.21Å
} (174)

ALUMINUM HYDRIDE

Mol. Wt.:
120.0

Formula:
$(AlH_3)_x$

M.P.:
d. 100°C (226)

Characteristics:
Solid - gray white (226)

Synthesis:

(1) $3LiAlH_4 + AlCl_3 \rightarrow 4(AlH_3) + 3LiCl$ (117)

(2) $3LiH + AlCl_3 \xrightarrow{ether} AlH_3 + 3LiCl$ (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:
$As(SiH_3)_3$

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.:
328.54

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)

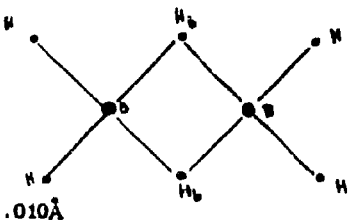
Flammability:

Spontaneously flammable (226).

DIBORANE

Mol. Wt.:	Formula:	Synonyms
26.67	B_2H_6	Boron hydride Boroethane
M.P.:	Characteristics	V.P.:
-165.5°C (226)	Gas - colorless sickly sweet odor (195)	224^{-112} (195)
d./sp.gr.:	B.P.:	V.d.:
(liq) $.447^{-112}$ (195) (sol) $.577^{-183}$ (195)	-92.5 (226)	.96 (142)

Structure:



B - H = 1.87 ± .010Å
B - H_b = 1.334 ± .027Å
B - B = 1.77 ± .013Å (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/m^3) of air (195).

Synthesis

(1) $6LiH + 8BF_3 \cdot O(C_2H_5)_2 \longrightarrow B_2H_6 + 6LiBF_4 + 8(C_2H_5)_2O$ (80)
(2) $3LiBH_4 + 4BF_3 \cdot O(C_2H_5)_2 \rightarrow 2B_2H_6 + 3LiBF_4 + 4(C_2H_5)_2O$ (80)
(3) $6NaH + 2BCl_3 + 6AlCl_3 \xrightarrow{\text{benzene}} B_2H_6 + 6NaAlCl_4$ (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) $HCHO + 2BBr_3 \xrightarrow[Cu]{400°C} B_2H_6 + HBr + CO +$ 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 pentaborane 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 H_2O (d. to H_3BO_3 and H_2); s NH_4OH, concentrated H_2SO_4 (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 moments 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 (190).

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

DISILYAMINO DIBORANE

Mol. Wt.:	Formula	Characteristics:
102.92	$B_2H_5N(SiH_3)_2$	Liquid - straw (226).
M.P.:	**B.P.:**	**V.P.:**
-68.8°C (226)	54°C (226)	$7.974-1669/T$; 162^0 (226)

Solubility:
s. organic solvent; d. H_2O (226)

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

Flammability:
Spontaneously flammable (226).

TETRABORANE

Mol. Wt.:	Formula:	Synonyms:
53.96	B_4H_{10}	dihydrotetraborane
		borobutane
M.P.:	**Characteristics:**	tetraboron decahydride
-120°C (226)	Gas - colorless (226)	boron hydride
d./sp. gr.:	**B.P.:**	**V.P.:**
$.56^{-35}$ (226)	16°C (226)	580^6, 388^0 (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)

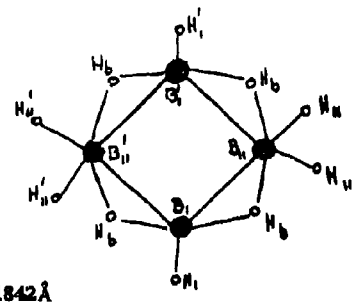
Thermodynamic properties:

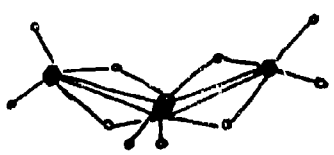
heat of vaporization: 6.47 kcal/mol (226)

Flammability:

Spontaneously flammable in air (226).

Structure:





$B_1 - B_{11} = 1.842Å$
$B_1 - B_1' = 1.712Å$
$B_{11} - B_{11}' = 2.800Å$
$B - H = 1.10Å$ (174)
$B_1 - H_b = 1.16Å$
$B_{11} - H_b = 1.37Å$

PENTABORANE
(Stable)

Mol. Wt.:
63.13

Formula:
B_5H_9

Synonyms:
Pentaboron enneahydride

M.P.:
-46.82°C (79)

Characteristics:
Gas - colorless, bad odor
Liquid - colorless, bad odor

V.P.:
66^0 (195)

d./sp. gr.:
$.66^0$ (79)

$n^{24}_{D_1}$ (49)
1.4445

V.d.:
2.2 (195)

B.P.:
58.4°C (79)

Toxicity:

Maximum tolerance .005 ppm (.01 mg/m^3) (195); an hour after a 1½ minute exposure to pentaborane during a disposal operation the men experienced psychomoter function difficulties, memory

blocking, lack of coordination, feelings of detachment ("classic" systems of boron toxicosis) irrationality loss followed for four days (5).

Synthesis

$B_2H_6 \xrightarrow[\text{excess } H_2]{\text{pyrolysis}} B_5H_9$ (140)

480°F

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 temperatures

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)

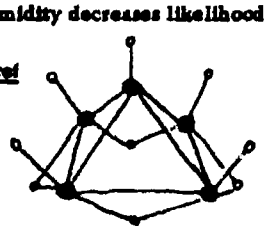
Military and industrial uses

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:



B - B = 1.66 - 1.77Å
B - H = 1.20 - 1.35Å (49)

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.:
52.8^0; $7.2^{-33.4}$ (226)

B.P.:
63°C (195)

Toxicity:
Tolerance: .005 ppm (.01 mg/m^3 air) (195)

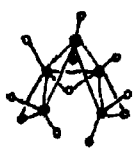
Unique conditions, reaction products:
On standing for a long period of time or heating, it produces diborane, tetraborane, hydrogen, pentaborane, decaborane and brown nonvolatile liquids and solids; hydrolyses in water to boric acid and hydrogen, reacts with ammonia to form tetraammoniate (132).

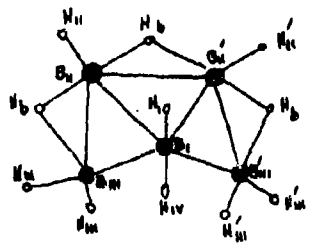
Solubility:
d. alcohol, air (226)

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

Flammability:
Spontaneously flammable (226).

Structure:





$B_1 - B_{11} = 1.72Å$
$B_1 - B_{111} = 1.87Å$
$B_{11} - B_{111} = 1.76Å$
$B_{11} - B'_{11} = 1.77Å$
Ave B - H = 1.10Å
Ave B - H_b = 1.22Å
$B_1 - H_{IV} = 1.09Å$
$B_{111} - H_{1V} = 1.72Å$
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.:
7^0 (226)

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

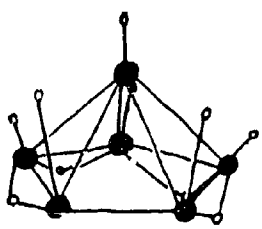
B.P.:
110°C (226)

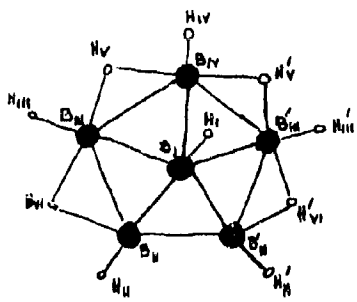
V.d.:
2.6 (195)

Solubility:
d. H_2O, alcohol (226)

Flammability:
Spontaneously flammable (226).

Structure:





$B_1 - B_{11} = 1.795 \pm .010$Å
$B_1 - B_{111} = 1.753 \pm .009$Å
$B_1 - B_{1v} = 1.740 \pm .014$ Å
$B_{11} - B'_{11} = 1.596 \pm .012$Å
$B_{11} - B_{111} = 1.737 \pm .010$Å
$B_{111} - B_{1v} = 1.794 \pm .009$Å
$B_1 - H_1 = 1.25 \pm .06$Å
$B_{11} - H_{11} = 1.28 \pm .05$Å
$B_{11} - H_{v1} = 1.36 \pm .04$Å
$B_{111} - H_{111} = 1.18 \pm .04$Å
$B_{111} - H_{v1} = 1.31 \pm .04$Å
$B_{111} - H_v = 1.48 \pm .05$Å
$B_{1v} - H_{1v} = 1.14 \pm .06$Å
$B_{1v} - H_v = 1.32 \pm .06$Å
(174)

DIHYDROHEXABORANE

Mol. Wt.:
77.02

Formula:
B_6H_{12}

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:
$B_{10}H_{14}$

Synonyms:
Boron hydride
Decaboron tetradecahydride

M.P.:
99.5°C (226)

Characteristics:
Solid - white, crystal (226)

d./sp. gr.:
$.94^{25}$ (226)

B.P.:
213°C (226)

V.P.:
19^{100} (226)

Toxicity:
High as irritant, and on inhalation tolerance .05 ppm (.3 mg/m^3) air (195).

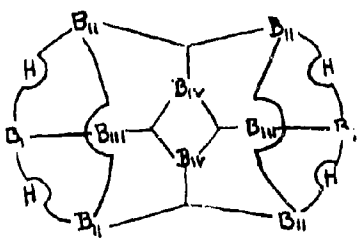
Solubility:
sl. s. cold H_2O; d. hot H_2O; s. alcohol, ether, benzene (79)

Thermodynamic properties
standard heat of formation 8 kcal/ mol (79)
heat of combustion 1950 kcal/mol (79)

	gas	liquid	
free energy of formation	71 kcal/mol	65 kcal/mol	(79)
standard entropy	15.09 e.u.	42.20 e.u.	
heat capacity	40.0 cal/°mol	52.09 cal/°mol	

Flammability:
Spontaneously flammable in air or O_2 (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:
BaH_2

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 H_2O (91)

Solubility:
d. cold H_2O 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/°mol (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.:	Formula:	Synonyms:
38.72	$Be(BH_4)_2$	Beryllium bis(tetrahydroboron)

M.P.:	V.P.:
d. 123°C (226)	.9[0] (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).

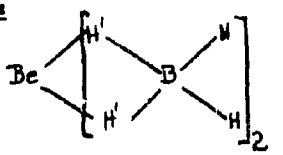
Thermodynamic properties:

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:



Be - B = 1.74Å
Be - H' = 1.53Å
B - H' = 1.28Å
B - H = 1.22Å
} (174)

BERYLLIUM HYDRIDE

Mol. Wt.:	Formula:
11.03	BeH_2

M.P.:	Characteristics:
d. 125°C (226)	Solid - white (226)

Synthesis:

(1) $Be(CH_3)_2 + LiAlH_4 \xrightarrow{Et_2O} BeH_2 + LiAlH_2(CH_3)_2$ (ether of composition not removable) (134)

(2) $Be(C_4H_{19})_2 \xrightarrow{\Delta} BeH_2 + 2C_4H_8$ (134)

Unique conditions, reaction products:

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

Solubility:
i. ether, toluene, isopentane (226)

CALCIUM HYDRIDE

M.P.:
> 1000°C (226)
816°C in hydrogen (195)

Formula:
CaH_2

Characteristics:
Solid - white crystals (226)

B.P.:
d. 1000°C (133)
d. 600°C (195)

d./sp. gr.:
1.9 (226)

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

Solubility:
d. with H_2O, lower alcohols, and carboxylic acids to form H_2 (132)

Thermodynamic properties:
heat of formation: 46.6 kcal/mol (226)

Military and industrial uses:
To generate H_2 (1g CaH_2 in $H_2O \longrightarrow$ 1 l H_2 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, $LiAlH_4$ or $NaAlH_4$, may have dust explosion if finely dispersed in air (133).

CERIUM (III) ALUMINOHYDRIDE

Mol. Wt.:
233.07

Formula:
$Ce(AlH_4)_3$

M.P.:
d. -80°C (13)

Synthesis:
From the solid complex with LiBr; treat the complex with $LiAlH_4$ near freezing point of the ether; a precipitate of the aluminohydride is yielded (13).

Flammability:
Spontaneously flammable (13).

CERIUM HYDRIDE

Mol. Wt.:
143.14

Formula:
CeH_3

Synonyms:
Trihydrocerine, cerous hydride

M.P.:
d. 1080°C (226)

Characteristics:
Solid - black powder (226)

V.P.:
$.5^{490-500}$ (226)

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

Solubility:
d. air, H_2O (226)

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

Flammability:
Spontaneously flammable (226).

COBALT TRIPHOSPHINE

Mol. Wt.:
157.85

Formula:
$Co(PH_2)_3$

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:
$Cs + 1/2H_2 \rightarrow CsH$ (80)

Solubility:
d. hot and cold H_2O, alcohol; i. organic solvents (79)

Thermodynamic properties:

	gas	crystalline	
heat of formation	29.0 kcal/mol	-10.1 kcal/mol	(31)
free energy of formation	24.3 kcal/mol	-7.3 kcal/mol (at 9°C)	(31)
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:
$CuAlH_4$

M.P.:
d. -70°C (13)

Synthesis
Form a solid complex with LiBr then treat with $LiAlH_4$ 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 H_2O; d. hot H_2O, HCl (103)

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

Flammability:
Spontaneously flammable in air when dry (234).

GALLIUM HYDRIDE

Mol. Wt.:
145.49

Formula:
Ga_2H_6

Synonyms
Digallane

M.P.:
-21.4°C (226)

Characteristics
Liquid - colorless (226)

V.P.:
2.5^0, 700130 (226)

B.P.:
139°C (extrapolated) (226)

Synthesis

$3Ga(CH_3)_3GaH_2(CH_3) + 4N(C_2H_5)_3 \rightarrow 4Ga(CH_3)_3 \cdot N(C_2H_5)_3 + Ga_2H_6$ (93)

Flammability:

Probably spontaneously flammable (93).

GERMANIUM HYDRIDE

Mol. Wt.:	Formula:	Synonyms
76.62	GeH_4	Germane
M.P.:	**Characteristics:**	**B.P.:**
-165°C (79)	Gas - colorless (79)	-88.5°C, d. 350°C (79)

d./sp. gr.:

1.523^{-142} (79)

Synthesis

(1) $GeMg_3 + 4NH_4Br \rightarrow 2MgBr_2 + 4NH_3 + GeH_4$ (80)

(2) $LiAlH_4 + GeX \xrightarrow[\text{solution}]{\text{ether}} GeH_4 + \ldots$ (132)

Solubility:

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

Thermodynamic properties

enthalpy -22.7 ± .5 kcal/mol (78)

heat of formation 21.6 ± .5 kcal/mol (78)

Flammability:

Decomposes in air often bursting into flames (80).

GERMANIUM HYDRIDE

Mol. Wt.:	Formula:	Synonyms
151.25	Ge_2H_6	Digermane
M.P.:	**Characteristics**	**B.P.:**
-109°C (79)	Liquid (79)	29°C (79)

d./sp. gr.:

1.98^{-109} (79)

Synthesis

$GeMg_2 + HCl(aqueous) \rightarrow Ge_2H_6 + \ldots\ldots$ (80).

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.:	Formula:	Synonyms
225.83	Ge_3H_8	Trigermane
M.P.:	**Characteristics**	**B.P.:**
-105.6°C (79)	Liquid - colorless (79)	110.5°C (d. 195°C) (79)
d./sp. gr.:		
2.2^{20} (79)		

Synthesis
(1) $GeMg_2 + HCl(aqueous) \rightarrow Ge_3H_8 + \ldots$ (80)

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

Flammability:
Decomposes in air often bursting into flames (80).

SODIUM HYDRIDE

Mol. Wt.:	Formula:	d./sp. gr.:
24.00	NaH	1.396 (226)
M.P.:	**Characteristics**	n_D:
d. 800°C (79)	Solid - gray white crystal powder (226)	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:

	gas	crystalline	
standard heat of formation:	29.88 kcal/mol	-13.60 ± .24 kcal/mol (at 101°C)	(31)
standard free energy of formation:	27.78 kcal/mol	-9.0 kcal/mol (at 90°C)	(31)
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: $NaPH_2$

Synthesis:
Pass hydrogen phosphide into solution of sodammonium in liquified ammonia, the gas is absorbed and hydrogen is evolved (quantity of H_2O generated corresponds to the formation of $NaPH_2$). 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: $Hf(BH_4)_4$

M.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^t: 1.453 (79)

d_4/sp. gr.: 1.47 (79)

Synthesis

$K + H_2 \xrightarrow[400°C]{\Delta}$ [illegible] electrodes in H_2 stream, pass electric arc through electrodes) (89)

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

	gas	crystalline
heat of formation:	30.0 kcal/mol	15.15 ± .16 kcal/mol
free energy of formation:	25.1 kcal/mol	(90°C) -8.9 kcal/mol (?1)
entropy:	47.3 cal/°mol	(102 mm) 10.2 cal/°mol

Flammability:

Ignites at lower temperature than NaH (39), spontaneously flammable (30).

LITHIUM ALUMINUM DEUTERIDE

d./sp. gr.:
$1.02^9/cm^3$ (195)

Formula:
$LiAlD_4$

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:
$LiAlH_4$

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

(1) $4LiH + AlCl_3 \rightarrow LiAlH_4 + 3LiCl$ (80)

(2) $4LiH + AlBr_3 \rightarrow LiAlH_4 + 3LiBr$ (80)

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): -185.87 kcal/mol (45)

Military and industrial uses
Powerful reducing agent for organic compounds (68).

Flammability:
Spontaneously flammable in H_2O (68).

LITHIUM ALUMINUM TRI-TERT-BUTOXYHYDRIDE

Mol. Wt.:
254.04

Formula:
$LiAl[OC(CH_3)_3]_3H$

Synonyms:
LATB
lithium tri-tert-butoxyaluminohydride

M.P.:
d. > 409°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 H_2O to evolve H_2, usually does not ignite" (190).

LITHIUM BOROHYDRIDE

Mol. Wt.:
21.78

Formula:
$LiBH_4$

M.P.:
d. 279°C (79)

Characteristics
Solid - rhombic crystals, white cubic crys. (79)

d./sp. gr.:
.66 (79)

Synthesis

(1) $4LiH + BF_3 \cdot O(C_2H_5)_2 \rightarrow LiBH_4 + 3LiF + O(C_2H_5)_2$ (80)

(2) $2LiH + B_2H_6 \rightarrow 2LiBH_4$ (30)

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.:	Formula:
7.95	LiH
M.P.:	**Characteristics**
680°C (79)	Solid - white cyrstals (79)
d./sp. gr.:	**B.P.:**
.82 (79)	d. 850°C (133)

Toxicity:

Tolerance level - .025 mg/m^3 (195).

Synthesis

$Li + 1/2H_2 \xrightarrow{700°C} LiH$ (133)

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)

	gas	crystalline	
entropy (at 25°C):	40.77 cal/°mol	5 cal/°mol	(30)
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 H_2, condensing agent with ketones and acid esters (132).

Flammability:
Can ignite spontaneously in moist air (195).

MAGNESIUM HYDRIDE

Mol. Wt.:
26.33

Formula:
MgH_2

M.P.:
d. 280°C (79)

Characteristics:
Solid - white tetragonal crystal or mass (79)

d./sp. gr.:
1.419 (79)

Synthesis:
$Mg + H_2 \rightarrow MgH_2$ (80)

Unique conditions, reaction products:
Violent reaction with H_2O ($MgH_2 + 2H_2O \rightarrow Mg(OH)_2 + H_2$) (132).

Solubility:
Violent d. cold H_2O; 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 + H_2O; also ignites with tap water but not in distilled H_2O (132).

MANGANESE (II) ALUMINOHYDRIDE

Mol. Wt.:
116.90

Formula:
$Mn(AlH_4)_2$

M.P.:
d. -80°C (13)

Synthesis:
Form solid complex with LiBr, heat complex with $LiAlH_4$ near freezing point of ether, yields a precipitate of aluminohydride (13).

Flammability:
Spontaneously flammable (13)

TRISILICYLAMINE

Mol. Wt.:	Formula:	Synonyms
107.34	$(SiH_3)_3N$	Nitrilo - Tri - silane Trisilylamine Nitrosilane
M.P.:	Characteristics	
-105.6°C (226)	Liquid - colorless (226)	
d./sp. gr.:	B.P.:	
.895^{-106} (226)	52°C (226)	

Unique conditions, reaction products:
Reacts with H_2O or steam to produce flammable vapors (94).

Solubility:
s. organic solvent (226)

Flammability:
Spontaneously flammable (226).

SODIUM ALUMINUM HYDRIDE

Mol. Wt.:	Formula:
54.00	$NaAlH_4$
M.P.:	d./sp. gr.:
d. 183°C (190)	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

Formulas:
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
(1) $Ca_3P_2 + 6H_2O \rightarrow 3Ca(OH)_2 + P_2H_4 + H_2$ (131)
(2) Acetyl chloride reacts with $4H_3PO_2 \rightarrow H_3PO_4 + H_3PO_3 + H_2 + P_2H_4$ (131)

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

Thermodynamic properties
heat of vaporization: 6.85 kcal (231)
trouton's constant: 21 (231)

Flammability:
Spontaneously flammable in air (143).

PHOSPHINE

Mol. Wt.:
34.00

Formulas:
PH_3

Synonyms:
Hydrogenphosphide
Phosphoretted hydrogen
Phosphorus trihydride

M.P.:
-133.5°C (226)

Characteristics:
Gas - colorless (226)

d./sp. gr.:
1.317^{-1} (226)
1.529^{0} (226)

B.P.:
-87.4°C (226)

Toxicity:
Moderate; high on inhalation, moderate as irritant; tolerance .05 ppm (.07 mg/m^3 air); central nervous system depressant; irritates lungs, dilates heart, can cause hyperemia of visceral organs (195).

Synthesis
(1) $4P + 3KOH + 3H_2O \rightarrow PH_3 + 3KH_2PO_2$ (80); (2) $Ca_3P_2 + 6H_2O \rightarrow 2PH_3 + 3Ca(OH)_2$ (80);
(3) $PH_4I + KOH \rightarrow PH_3 + KI + H_2O$ (80)

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

Solubility:
sl. s. H_2O; 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:
$P(SiH_3)_3$

Characteristics:
Liquid - colorless (226)

V.P.:
83 mm (at 0°C) (226)

Solubility:
d. H_2O; s. organic solvent (226).

Flammability:
Spontaneously flammable (226).

PLUTONIUM HYDRIDE

Mol. Wt.:
244.02

Formula:
PuH_2

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

$Rb + H_2 \xrightarrow[\text{(high temperature)}]{620\text{-}680^\circ C} RbH$ (89)

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

	gas	crystalline
heat of formation	33.0 kcal/mol	-11.3 kcal/mol (at 102°C) (31)

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.:	Formula:	Synonyms
$(30.10)_x$	$(SiH_2)_x$	Polysilanes

Toxicity:

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

Synthesis

$CaSi + 2HCl \rightarrow (SiH_2)_x + CaCl_2$ (80).

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.:	Formula:	Synonyms
32.12	SiH_4	Silicon tetrahydride
		Silicon hydride
M.P.:		Silicane
-185°C (226)	Characteristics	
	Gas - colorless (226)	
d./sp. gr.:	B.P.:	
(liq) .68 -185 (226)	-111.8°C (226)	
(gas) 1.44 (195)		

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

Synthesis:
(1) $SiMg_2 + 4NH_4Br \xrightarrow[-33°C]{\text{liquid } NH_3} SiH_4 + 2MgBr_2 + 4NH_3$ (132)

(2) $LiAlH_4 + SiCl_4 \xrightarrow{\text{ether solution}} SiH_4 + LiCl + AlCl_3$ (132)

(3) $SiMg_2 + 4HCl \xrightarrow{50°C} SiH_4 + 2MgCl_2$ (132)

Solubility:
d. air, alkaline solvents, o. organic solvents (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
$Si + PH_2 \xrightarrow{450°C} H_3SiPH_2$ (157)

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

Mol. Wt.:
62.23

Formula:
Si_2H_6

Synonyms:
Silicoethane

M.P.:
-132.5°C (226)

Characteristics:
Gas - colorless (226)

d./sp. gr.:
$.686^{-25}$ (226)

B.P.:
-15°C (226)

Unique conditions, reaction products:
Explodes with SF_6; reacts violently with CCl_4 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

Mol. Wt.:
92.33

Formula:
Si_3H_8

Synonyms:
Trisilicon octahydride
Trisilane propane
Silicon hydride

M.P.:
-117.4°C (226)

Characteristics:
Liquid - colorless (226)

V.P.:
95.5^{0} (195)

d./sp. gr.:
$.743^{0}$ (226)
$.725^{25}$ (226)

B.P.:
53°C (226)

Solubility:
s. organic solvent; d. H_2O, CCl_4 (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

Mol. Wt.:
222.56

Formula:
$Si_6O_3H_6$

Synonyms:
Hexaoxocyclosilane

M.P.:
d. 140°C (79)

Characteristics:
Solid - white platelets (79)

d./sp. gr.:
1.32^{20} (79)

Solubility:
sl. d. cold H_2O; slight d. hot H_2O (79); d. air (79)

Flammability:
Spontaneously flammable (50)

STRONTIUM HYDRIDE

Mol. Wt.:
89.64

Formula:
SrH_2

M.P.:
d. 675°C (79)

Characteristics:
Solid - white crystalline (226)

d./sp. gr.:
3.72 (226)

B.P.:
Sublimes 1000°C (in H_2) (79)

Synthesis:
$Sr + H_2 \longrightarrow SrH_2$ (80)

Unique conditions, reaction products:
Vigorous reaction with H_2O (226)

Solubility:
d. hot and cold H_2O, 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

Mol. Wt.:
235.07

Formula:
ThH_3

Characteristics:
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: $U(BH_4)_3$

Characteristics:
Solid - brown
non volatile (197)

Toxicity:
Treat UF_4 with $Al(BH_4)_3$ at room temperature. The dark green volatile crystals of $U(BH_4)_4$ decompose very slowly at room temperature, at 100°C, however, gives

$$U(BH_4)_3(\text{pyrophoric}) + H_2 + B_2H_6\ [2U(BH_4)_4 \xrightarrow{100°C} 2U(BH_4)_3 + B_2H_6 + H_2]\ (197)$$

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:
$U\ (\text{very pure}) + \frac{3}{2}H_2 \rightarrow UH_3$ (80)

Unique conditions, reaction products:
Powerful reducing agent; vigorous reaction with H_2O ($2U_3 + 4H_2O \rightarrow 2UO_2 + 7H_2$) (80).

Flammability:
Spontaneously flammable (80).

ZIRCONIUM BOROHYDRIDE

Mol. Wt.:
150.50

Formula:
$Zr(BH_4)_4$

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 $(CH_3)_2NBH_2 \rightarrow (CH_3)_2NB_2H_5$ and aminoborohydrides of aluminum (30).

Unique conditions, reaction products
Violently attacked by air or moisture (30); reacts with diborane to yield $(CH_3)_2NB_2 + Al(BH_4)_3$ (30).

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

(h) NITRIDES

TRIAZIDO BORINE

Mol. Wt.:	Formula:
136.82	$B(N_3)_3$

Unique conditions, reaction products:
Explodes above -45°C or when added to H_2O (156).

BARIUM AZIDE

Formula:
BaN_6

Unique conditions, reaction products:
Heat in vacuum to 140-160°C → pyrophoric residue (227).

Flammability:
Spontaneously flammable (227)

CALCIUM NITRIDE

Mol. Wt.:	Formula:
148.25	Ca_3N_2

M.P.:	Characteristics	d./sp. gr.:
1195°C (79)	Solid - brown hexagonal	2.6[illegible]7 (79)
900°C (195)	crystal (79)	

Synthesis:
$3Ca + N_2 \rightarrow Ca_3N_2$ (80)

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

Thermodynamic properties:

	crystal	
standard heat of formation	-103.2 kcal/mol	(79)
free energy of formation (at 25°C):	-88.1 kcal/mol	
entropy (at 25°C):	25 cal/°mol	

Flammability:
Spontaneously flammable in air (143).

CADMIUM NITRIDE

Mol. Wt.:
365.23

Formula:
Cd_3N_2

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

Synthesis:
$Cd(NH_2)_2 \xrightarrow[180°C]{\Delta \text{ vacuo}} Cd_3N_2 + NH_3$ (162).

Unique conditions, reaction products:
Violent explosion with H_2O (143); explodes on reaction with dilute acids and bases (131).

Thermodynamic properties:

	crystalline
standard heat of formation (at25°C):	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).

COBALT NITRIDE

Mol. Wt.:
72.94

Formula:
CoN

Characteristics:
Solid - black powder (80)

Synthesis:
$Co(HN_2)_3 \rightarrow CoN + 2NH_3$ (80); cobalt amide in vapor pressure eudiometer, decompose at 50°-70°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:
$S_4N_4 \xrightarrow{\text{thermal degradation}} 2S_2N_2$ (80)

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° - 160°C → pyrophoric residue (227)

Flammability:
Spontaneously flammable (227)

THORIUM NITRIDE

Mol. Wt.:
752.14

Formula:
Th_3N_4

Characteristics:
Solid - dark brown powder or black crystal (79)

Synthesis:

$$\left.\begin{array}{l} (1)\ 3Th + 2N_2 \rightarrow Th_3N_4 \\ (2)\ 3ThCl_4 + 2N_2 + 6H_2 \rightarrow Th_3N_4 + 12HCl \\ (3)\ 3ThO_2 + 6C + 2N_2 \rightarrow Th_3N_4 + 6CO \end{array}\right\} (80)$$

Unique conditions, reaction products:
Burns in air with incandescence (143).

Solubility:
sl. d. cold H_2O; d. hot H_2O; s. HCl (79)

AZIDO THALLIUM

Mol. Wt.:
246.39

Formula:
TlN_3

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 hither nitrides with hydrogen; (4) direct reaction of ammonia or nitrogen with uranium hydride; or (5) direct reaction between nitrogen and uranium (131).

Thermodynamic properties

	crystalline	
standard heat of formation	-80 kcal/mol	(79)
standard free energy of formation	-75 kcal/mol	(79)
entropy (at 25°C)	18 cal/°mol	(79)

Flammability

Spontaneously flammable (240).

BARIUM PEROXIDE

Mol. Wt.:
169.34

Formula:
BaO_2

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 O_2) (79)

Toxicity:
Slight as irritant on ingestion and on inhalation (195); threshold limiting value .5 mg/m^3 (142).

Synthesis:
$BaO \xrightarrow{O_2}$ (190)

Unique conditions, reaction products:
Reacts with large quantities H_2O explosively (144).

Solubility:
v. sl. s. cold H_2O; d. hot H_2O; 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 H_2O, dilute HNO_3 (79)

Flammability:
Spontaneously flammable (50).

CESIUM OXIDE

Mol. Wt.:
281.81

Formula:
Cs_2O

M.P.:
d. 400°C (79)
420°C in N_2 (79)

Characteristics:
Solid - orange needles (79)

d./sp. gr.:
4.25 (79)

Synthesis:
$2Cs + 1/2O_2 \rightarrow Cs_2O$ (80)

Solubility:
v. s. cold H_2O; d. hot H_2O; s. acid (79)

Thermodynamic properties:

	crystalline
standard heat of formation:	-75.9 kcal/mol (79)
entropy:	23 e.u. (79)

Flammability:
Spontaneously flammable in H_2O (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)

$\frac{n}{D_s}$
2.32 (79)

Synthesis:
(1) Thermal decomposition of iron formate or iron oxalate results in carbon bearing FeO ($FeC_2O_4 \longrightarrow FeO + CO + CO_2$) (116); (2) decompose FeC_2O_4 in quartz vessel, lower section (850°C) remove nascent gases as quickly as possible, FeC_2O_4 trapped in heated portion when FeO is formed (all gas is removed) chill quickly (to prevent decomposition) (80); (3) heat Fe_2O_3 and reduced iron in sealed preevacuated quartz tubes 3 days at 900°C (80).

Thermodynamic properties

temperature of transition	1641°K	(79)
heat of transition	7.5 kcal/mol	
entropy (at 298°K)	12.9 e.u.	

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

	gas	
standard heat of formation	91 kcal/mol	(79)
temperature of transition	600°K	
heat of transition	4.5 kcal/mol	
entropy (at 298°K)	14.5 e.u.	

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

	crystalline	
standard heat of formation	-118 kcal/mol	(79)
temperature of transition	980°K	
heat of transition	6.8 kcal/mol	
entropy (at 298°K)	23 e.u.	

Flammability:
Ignites or explodes with H_2O (218).

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$_4^{20}$ (79)

B.P.: d. 55°C (explodes 95°C) (79)

Unique conditions, reaction products:
Forms in $KMnO_4$ - H_2SO_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:
$MoO_3 + H_2 \xrightarrow{300°C} MoO_2$ (240)

Solubility:
i. cold and hot H_2O; sl. s. hot concentrated H_2SO_4; i. alkaline solvent, HCl, HF (79)

Thermodynamic properties:

	crystalline	
Heat of formation (at 25°C):	-130 kcal/mol	(79)
temperature of transition:	2200°K	
heat of transition:	16 kcal/mol	
entropy (at 298°K):	14.5 e.u.	

Flammability:
Spontaneously flammable (240).

MOLYBDENUM TRIOXIDE

Mol. Wt.:
143.94

Formula:
MoO_3

Synonyms
Molybdic anhydride
Natural molybdite

M.P.:
795°C (79)

Characteristics
Solid - colorless, or white yellow rhombic

d./sp. gr.:
4.692^{21} (79)

B.P.:
(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. H_2O; s. HNO_3 and concentrated HCl solution (190); s. acids, alkaline sulfides, NH_4OH (79)

Thermodynamic properties

	crystalline	aqueous solution	
standard heat of formation	-180.33 kcal/mol	-188.1 kcal mol	(79)
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		

Flammability:
Spontaneously flammable (238)

PHOSPHORUS TRIOXIDE

Mol. Wt.:
109.95

Formula:
P_2O_3

Synonyms
Diphosphorus trioxide

M.P.:
23.8°C (79)

Characteristics
Solid - colorless or white powder or monoclinic deliquescent (79)

V.P.:
$10^{53.0}$ (195)

d./sp. gr.:
2.135^{21} (79)

B.P.:
173.8°C (N_2 atmosphere) (79)

Synthesis
Precipitated by treating PCl_3 with tetramethyl ammonium sulfite in liquid SO_2

$$2PCl_3 + 3[(CH_3)_4N]_2SO_3 \rightarrow P_2O_3 + 3SO_2 + 6[(CH_3)_4N]Cl \quad (132)$$

Solubility:
d. hot H_2O, cold H_2O to H_3PO_3; s. C_6H_6, CS_2, ether, chloroform (79)

Flammability:
Melted P_2O_3 readily ignites in air; when thrown into O_2 at 50-60°C ignites with brilliant flame (143).

SULFUR TRIOXIDE

Mol. Wt.:
80.06

Formula:
SO_3

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:

	gas	liquid	
standard heat of formation	-94.45 kcal/mol	-104.57 kcal/mol	(79)
free energy of formation (at 25°C)	-88.52 kcal/mol		
entropy (at 25°C)	61.24 cal/°mol		

Military and industrial uses:
German army used SO_3 for smoke screens in World War I (23).

TRISULPHUR DINITROGEN DIOXIDE

Mol. Wt.:
156.18

Formula:
$S_3N_2O_2$

M.P.:
100.7°C (without d.)

Characteristics:
Solid - pale yellow crystals (80)

Synthesis:
$S_4N_4 + 4SOCl_2 + 4SO_2 \rightarrow 2S_3N_2O_2 + 4SO_2Cl_2 + 2S$ (80)

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 H_2O; s. dilute HF and HNO_3 (79)

Thermodynamic properties
temperature of transitions 2550°K
heat of transitions 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
$Ti + TiO_2 \rightarrow 2TiO$ (80)

Solubility:
s. dilute H_2SO_4; i. HNO_3 (79); s. dilute HCl [$Ti^{++} + H^+ \rightarrow Ti^{+++} + \frac{1}{2}H_2$] (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
entropy (at 298°K): α 2.31 e.u.
(79)

Flammability:
Spontaneously flammable (50).

URANIUM OXIDE

Mol. Wt.:
270.03

Formula:
UO_2

Synonyms
Uranous oxide
Uranium dioxide

M.P.:
2500°C (79)
2176°C (under N_2) (80)

Characteristics
Solid - brown, black rhombic or cubic (79)

d./sp. gr.:
10.96 (79)

Synthesis:
$UO_2C_2O_4 \cdot 3H_2O \rightarrow UO_2 + 2CO_2 + 3H_2O$ (preparation of hot concentrated solution of uranyl nitrate with oxalic acids yields a yellow powder of $UO_2C_2O_4 \cdot 3H_2O$ 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:

	crystalline	
standard heat of formation:	-270 kcal/mol	(79)
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 HYDRIDE

Mol. Wt.:
273.07

Formula:
$UH(OH)_2$

Synthesis:
Metal uranium dissolves in excess HCl(6N), drying the precipitate in a vacuum yields $UH(OH)_2$ (102)

Unique conditions, reaction products:
With aqueous $KMnO_4$ yields hydrogen, with heat yields $U_3O_8 + H_2$ (102)

Flammability:
Spontaneously flammable (240).

VANADIUM SESQUIOXIDE

Mol. Wt.:
149.88

Formula:
V_2O_3

Synonyms:
Vanadium trioxide

M.P.:
1970°C (79)

Characteristics:
Solid - black crystal (79)

d./sp. gr.:
4.87^{18}_{4} (79)

Solubility:
sl. 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.:
2.85^{15}_{4} (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 the aluminum phosphide mixture, ignite in a small hot flame and drive out excess phosphorus (80).

Unique conditions, reaction products:
Yields phosphine on reaction with H_2O (132)

CALCIUM PHOSPHIDE

Mol. Wt.:
182.19

Formula:
Ca_3P_2

Synonyms:
Photophor

M.P.:
Ca 1600°C (79)

Characteristics:
Solid - gray lumps (79)

d./sp. gr.:
2.51 (79)

Synthesis:
(1) $3C + 2P \rightarrow CaP_2$; (2) $3Ca_3(PO_4)_2 + 16Al \rightarrow 3Ca_3P_2 + 8Al_2O_3$ (cannot separate Ca_3P_2 and Al_2O_3) (80)

Solubility:
d. in cold H_2O; s. acids; l. alcohol, ether, C_6H_6 (132)

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

Military and industrial uses:
Used to prepare P_2H_4 (80); used in signal fires (132).

Flammability:
With water produces phosphine (PH_3) and diphosphine (PH_2); 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

Mol. Wt.:
149.66

Formula:
SnP

Synonyms:
Tin monophosphide
Tin phosphide

M.P.:
Decomposes (79)

Characteristics:
Solid - silver white crystal (79)

d./sp. gr.:
6.56 (79)

B.P.:
Decomposes (79)

Unique conditions, reaction products:
Reacts with moisture to yield phosphine (195).

Solubility:
d. hot H_2O (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 H_2O 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:
Li_6Si_2

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 NH_3 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 H_2O; d. alcohol; i. NH_3, turpentine (79)

SODIUM SILICIDE

Mol. Wt.:	Formula:
51.1	NaSi

Flammability:
Spontaneously flammable as loose powder (50); spontaneously flammable and explosive with H_2O or dilute acid (80).

(1) SULFIDES

BARIUM SULFIDE

Mol. Wt.:
169.43

Formula:
BaS

M.P.:
1200°C (79)

Characteristics
Solid - colorless cubic crystals (79)

d./sp. gr.:
4.25^{15} (79)

n_{Di}
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 H_2O filtered and evaporated (190)

Unique conditions, reaction products
With damp air decomposes to carbonate with evolution of H_2S (132).

Solubility:
d. in hot and cold H_2O; i. alcohol (79)

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

CARBON DISULPHIDE

Mol. Wt.:
76.14

Formula:
CS_2

Synonyms:
Dithiocarbonic anhydride
Carbon bisulphide

M.P.:
111°C (79)

Characteristics
Liquid - colorless (79)

V.P.:
400^{28} (195)

d./sp. gr.:
1.261^{22}_{20} (79)

B.P.:
46.3°C (79)

V.d.:
2.64 (195)

n^{18}_{Di}
1.62950 (79)

Toxicity:
Highly toxic when ingested, inhaled or absorbed, acutely and chronicly 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 H_2O 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 atms
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 CCl_4 (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)

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

Synthesis

(1) strongly heat pulverized calcium sulphate with charcoal (190)
(2) $CaCO_3 + H_2S \rightarrow CaS + H_2O + CO_2$ (80)

Solubility:

i. alcohol; sl. s. cold H_2O, hot H_2O (132); d. acid (79)

Flammability:

Air hazardous solid (27).

IRON SULFIDE

Mol. Wt.:
87.91

Formula:
FeS

Synonyms:
Ferrous sulfide
Nattrollite

M.P.:
1193-1199°C (79)

Characteristics:
Solid - black brown hexagonal (79)

d./sp. gr.:
4.74 (79)

B.P.:
Decomposes (79)

Synthesis:
$Fe + S \rightarrow$ 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 H_2O; sl. d. acid; i. NH_3 (79)

Flammability:
Spontaneously flammable (211).

POTASSIUM SULFIDE

Mol. Wt.:
110.27

Formula:
K_2S

Synonyms:
Potassium sulfuret

M.P.:
471°C (195)
912°C (80)

Characteristics:
Solid - yellow brown deliquescent cubic (79)

d./sp. gr.:
1.805^{14} (79)

Synthesis:
$2K + S \xrightarrow[\text{liquid}]{NH_3} K_2S$ (80)

Solubility:
s. cold H_2O, acid, glycerol; v. s. hot H_2O; i. ether (79)

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

SODIUM SULFIDE

Mol. Wt.:
78.04

Formula:
Na_2S

Synonyms:
Sodium monosulfide

M.P.:
1180°C (79)

Characteristics:
Solid - white deliquescent crystals (79)

d./sp. gr.:
1.852^{14} (79)

Synthesis:
(1) $2Na + S \xrightarrow[NH_3]{liquid} Na_2S$; (2) $Na_2S \cdot 9H_2O \rightarrow Na_2S + 9H_2O$ (80)

Solubility:
s. H_2O; 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 HYDROSULPHITE

Mol. Wt.:
174.10

Formula:
$Na_2S_2O_4$

Synonyms:
Sodium dithionate
Sodium sulfoxylate

M.P.:
d. 55°C

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

Synthesis:
Dissolve Zn in solution of sodium bisulfite; $Zn—Na_2S_2$ is precipitated by milk of lime leaving the hydrosulfite in solution, add salt and hydrosulfite of crystallation is precipitated, the latter is removed by treating with hot alcohol (190).

Solubility:
v. s. H_2O; 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 SESQUISULFIDE

Mol. Wt.:
220.09

Formula:
P_4S_3

Synonyms:
Phosphorus tetritatrisulfide
Tetraphosphorus trisulfide

M.P.:
172.5°C (195)

Characteristics:
Solid - yellow rhombic (79)

d./sp. gr.:
2.03^{17} (79)

B.P.:
407°C (195)

Toxicity:
Probably toxic (195).

Synthesis:
$4P + 3S \rightarrow P_4S_3$ (214)

Ignition temperature:
Autoignition temperature: 212°F (195)

Solubility:
i. cold H_2O; d. hot H_2O (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:
P_2S_5

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 H_2S if react with H_2O, threshold value of dust 1 mg/m^3 (142).

Synthesis:
$2P + 5S \rightarrow P_2S_5$ (80)

Ignition temperature:
287°F (142)
Autoignition temperature: 548.6°F (195)

Solubility:
i. cold H_2O; d. hot H_2O; s. alkaline solvent, .22 CS_2 (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 H_2O; s. aqua regia; sl. s. HNO_3 (79)

Flammability:

Spontaneously flammable in air (143)

(m) MISCELLANEOUS

HEXAMMINO CALCIUM

Mol. Wt.:
142.08

Formula:
$Ca(NH_3)_6$

Flammability:
Spontaneously flammable (50).

CHLOROSULFONIC ACID

Mol. Wt.:
116.52

Formula:
$ClSO_2OH$

M.P.:
-80°C (79)

Characteristics:
Liquid - colorless, fuming, pungent odor (79)

d./sp. gr.:
1.766^{18} (79)

B.P.:
158°C (79)

n_D^{14}
1.437 (79)

Toxicity:
Breaks down to HCl and H_2SO_4 with moisture in lungs (142); may produce severe acid burns, irritating to eyes, lungs, and mucous membranes, on ingestion seriously irritates mouth, esophagus and stomach, (195).

Synthesis:
(1) pass HCl into fuming $H_2SO_4 \rightarrow ClSO_2OH$ (214)
(2) react $SO_3 + HCl \rightarrow ClSO_2OH$ (214)

Unique conditions, reaction products:
$HClSO_3 + H_2O \rightarrow H_2SO_4 + HCl$ (170)

Solubility:
d. to H_2SO_4 and HCl in cold H_2O (79); d. alcohol acid; i. CS_2 (79)

Handling:
Keep tightly closed, decomposes with explosive violence in H_2O (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 N_2 atmosphere (absence of O_2) a centrifuged solution of $Fe(OH)_2$ (precipitated from pure $FeCl_2$) in concentrated aqueous solution of NH_3 is admitted through a filter diluted with H_2O. 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 H_2O as solid slowly melts, complete drying with P_2O_5 under high vacuum (80).

Unique conditions, reaction products:
When sprayed into air, burns with sparks (80).

Solubility:
cold H_2O $.0001516_{18}$; s. acid, NH_4Cl; i. alkaline solvent (79)

POTASSIUM CHLORATE

Mol. Wt.:
122.55

Formula:
$KClO_3$

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 calorate (190)

Solubility:
7.1^{20} cold H_2O; 57^{100} hot H_2O; 14.1^{100} 50% alcohol; sl. s. glycol, liquid NH_3; i. acetone; s. alkaline solvent (79).

Military and industrial uses:
Explosive, fireworks, matches, printing and dying cotton and wool black, source of O_2, 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°C to $MgCN_2$ (79)	d. 600°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).

$Na_4P_2 \cdot 2NH_3$

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

Formulas: $(NH_2)_2P(O)OH$

Synthesis
Treat phenyldichlorophosphate $Cl_2 \cdot PO \cdot OC_6H_5$ with NH_3 to convert it into phenyldiamidophosphate, and $(NH_2)_2POOC_6H_5$ and hydrolyze the product with a solution of potassium diamidophosphate. Heat the cold solution of this salt with CH_3COOH to form crystals of $(NH_2)_2POOH$ (131).

RUBIDIUM SILICIDE

Mol. Wt.: 113.5

Formulas: RbSi

Characteristics
Solid - small dark crystals (80)

Unique conditions, reaction products
Ignites explosively on contact with H_2O or dilute acids (80).

PROSILOXANE

Mol. Wt.: 46.09

Formulas: H_2SiO

Flammability:
Spontaneously flammable in air (143).

$Si_2N_4H_6$

Mol. Wt.:
118.18

Synthesis
$Si_2Cl_6 + NH_3 \rightarrow Si_2N_4H_6 + (Si_2N_2)_n$ (80)

Flammability:
Spontaneously flammable (50).

SILICOCYN

Mol. Wt.:	Formula:
(84.18)n	$(Si_2N_2)_n$

Synthesis:

$$Si_2Cl_6 + NH_3 \rightarrow Si_2N_4H_6 + \underline{(Si_2N_2)_n} \quad (50)$$

Flammability:

Spontaneously flammable (50)

TITANIUM BORIDE

Mol. Wt.:	Formula:
69.54	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:
$(C_6H_5)Ag$

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:
$C_2H_5AlCl_2$

Synonyms:
Ethyl aluminum dichloride

M.P.:
22°C (226)

Characteristics:
Liquid - yellow (226)

V.P.:
12^{80}
30^{100}
69^{120}
280^{168}
575^{180}
(226)

d./sp. gr.:
1.232^{25}

B.P.:
194°C (extrapolated) (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 H_2O (190)

Solubility:
d. H_2O, 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:
$Al(BH_4)_3 \cdot C_2H_6O$

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

TRIMETHYL ALUMINUM

Mol. Wt.:
72.02

Formula:
$(CH_3)_3Al$

Synonyms:
Trimethyl alumine

M.P.:
15.4°C (226)

Characteristics:
Liquid - colorless (226)

V.P.:
8.4 20
68.5 60
332 100
(226)

B.P.:
126°C (226)

Synthesis:
(1) $2Al + 3(CH_3)_2Hg \rightarrow 2(CH_3)_3Al + 3Hg$ (109)
(2) $Al_2Mg_3 + 6CH_3Cl \rightarrow 2(CH_3)_3Al + 3MgCl_2$ (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 shears, and turbulence at night (192); intermediate class of propellants (109).

Flammability:
Spontaneously flammable (226).

TRIMETHYL ALUMINUM BROMIDE

Mol. Wt.:
231.85

Formula:
$(CH_3)_3Al_2Br_2$

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.:
1 at 41
12 at 90
65 at 130
256 at 170
465 at [illegible]
(226)

d./sp. gr.:
$.958^{25}$ (226)

B.P.:
208°C (226)
(extrapolated)

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.:
$.808^{20}$ (103)

Characteristics
Liquid - colorless (103)

V.P.:
55-56 .001-.0001 (103)

n_D^{20}
1.4703 (103)

Synthesis:
$AlCl_3 + Al(C_2H_5)_3 \cdot O(C_2H_5)_2 \rightarrow Al(C_2H_5)_2Cl$; $Al(C_2H_5)_2Cl + LiH \rightarrow Al(C_2H_5)_2H + LiCl$ (80).

Solubility:
d. H_2O, air (103)

Flammability:
Spontaneously ignites in air (145).

TRIMETHYL ALUMINE DIMETHYL ETHER

Mol. Wt.:
118.11

Formula:
$(CH_3)_5Al(CH_3)_2O$

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.:
114.17

Formula:
$(C_2H_5)_3Al$

M.P.:
-46°C (226)

Characteristics:
Liquid - colorless (226)

V.P.:
$.004^{48-50}$
$.8^{60}$
13^{10}
110^{140}
(226)

d./sp. gr.:
$.8324^{25}$ (226)

B.P.:
194°C (226)
207°C (extrapolated) (226)

Specific heat:
.527 (at 33 mm)

$\frac{n_{D}^{6.5}}{1.480}$ (226)

Viscosity:
2.58 cp (at 25°C) (226)

Toxicity:
High, extremely destructive to living tissue (80).

Synthesis:
$Al(C_2H_5)_2Br + Na(wire) \rightarrow Al(C_2H_5)_3$ ... Heat flask of $Al(C_2H_5)_2Br$ and Na wire at 105°C (with external cooling) until reaction calms, add more $Al(C_2H_5)_2Br$ 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 $Al(C_2H_5)_3$ (80).

Unique conditions, reaction products:
Hydrolyzes to $Al(OH)_3$ immediately with moisture (80); explodes violently with H_2O (143).

Ignition temperatures
flash point: < -52.5°C (195)
autoignition temperature: < -52.5°C (195)

Solubility:
s. organics; decomposes H_2O, 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:
$(C_3H_7)_2AlH$

Flammability:
Ignites spontaneously in air (145).

TRIMETHYL ALUMINE-DIETHYL ETHER

Mol. Wt.:
146.21

Formula:
$(CH_3)_3Al \cdot O(C_2H_5)_2$

Characteristics
Liquid (226)

V.P.:
15^{68} (226)

Solubility:
s. organic solvent; d. H_2O (226)

Flammability:
Spontaneously flammable (226).

DIISOBUTYL ALUMINUM CHLORIDE

Mol. Wt.:
176.67

M.P.:
-39.5°C (103)

d./sp. gr.:
$.9088^{20}_{20}$ (103)

Formula:
$AlCl(iso\text{-}C_4H_9)_2$

Characteristics
Liquid - colorless (103)

n^{20}_{D}
1.4506 (103)

Synonyms
Di-i-butylchloroalumine

V.P.:
10^{152}
5^{138}
1^{108}
(103)

Viscosity:
5.11 cps (at 20°C) (103)

Unique conditions, reaction products:
Yields dense white smoke on reaction with H_2O; $AlCl(isoC_4H_9)_2 + H_2O \rightarrow Al(OH)_2Cl + 2iso\text{-}C_2H_{10}$ (111).

Solubility:
s. organic solvents; d. H_2O (103)

Flammability:
High spontaneous exothermic reaction (may flame) on contact with air (111).

DIISOBUTYL ALUMINUM HYDRIDE

Mol. Wt.:	Formula:	B.P.:
142.06	$(i\text{-}C_4H_9)_2AlH$	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.:	Formula:	
156.25	$(n\text{-}C_3H_7)_3Al$	
M.P.:	Characteristics:	
-107°C (103)	Liquid - colorless (103)	
d./sp. gr.:	B.P.:	V.P.:
$.823^{20}$ (103)	248-252°C (103)	15^{65} (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 H_2O (143).

Solubility:
s. organic solvents; d. H_2O (103).

Flammability:
Pyrophoric (190).

TRIPROPYL ALUMINUM

Mol. Wt.:
156.25

Formula:
$(i\text{-}C_3H_7)_3Al$

Synonyms:
Isopropylaluminum

M.P.:
-107°C (103)

Characteristics:
Liquid - colorless (103)

V.P.:
1^{65} (103)

d./sp. gr.:
$.823^{20}$ (103)

B.P.:
248-252°C (103)

Solubility:
s. organic solvents; d. H_2O (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.:
16^{112} (226)

Flammability:
Spontaneously flammable (226)

DIETHYLDIETHYL AMINO-3-PROPYL ALUMINE

Mol. Wt.:
199.32

Formula:
$(C_2H_5)_2Al(CH_2)_3N(C_2H_5)_2$

M.P.:
-2°C (226)

Characteristics
Liquid - straw (226)

V.P.:
2^{97} (226)

Solubility:
s. organic solvents; d. air (226)

Flammability:
Spontaneously flammable (226)

TRI-n-BUTYLALUMINUM

Mol. Wt.:
198.33

Formula:
$(n\text{-}C_4H_9)_3Al$

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:
$(C_4H_9)_3Al$

Synonyms:
Triisobutylalumine

M.P.:
1.0 - 4.3°C (103)

Characteristics
Liquid - colorless (103)

V.P.:
147 (103)

d./sp. gr.:
$.7859^{20}$ (103)

n_D^{20}
1.4404 (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 H_2O, acids, halogens, alcohols and amines (190).

Ignition temperature:
flash point: < 4°C (195)
autoignition temperature: < 4°C (195)

Solubility:
d. H_2O, 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:
$(C_6H_5)_3Al$

M.P.:
230°C (103)

Characteristics
Solid - white (103)

Solubility:
d. (explosively) H_2O; s. organics (190)

1, 1, 1-TRIMETHYL TRIBROMO DIALUMENE

Mol. Wt.:
338.81

Formula:
$(CH_3)_3AlAlBr_3$

Synonyms
Methyl aluminum sesquibromide

M.P.:
4°C

Characteristics
Liquid - yellow (226)

d./sp. gr.:
1.514^{25} (226)

B.P.:
166°C (extrapolated) (226)

V.P.:

15	60	(226)
39	80	
89	100	
185	120	
359	140	
650	160	

Viscosity:
2.76 cp (at 23.3°C) (226)

Unique conditions, reaction products
Violent reaction with H_2O (190)

Solubility:
s. organic solvent; d. H_2O (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:
$(CH_3)_3Al_2Cl_3$

B.P.:
143.7°C (extrapolated) (190)

F.P.:
22.8°C (190)

d./sp. gr.:
1.629^{25} (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.:	Formula:	Synonyms:
102.09	$(CH_3)_2HAlAlH_2CH_3$	Trimethyl aluminum hydride

Unique conditions, reaction products:
Vigorous reaction with $H_2O \longrightarrow CH_4 + H_2 + Al_2O_3$ (92)

Solubility:
d. air, H_2O (226)

Flammability:
Spontaneously flammable (92)

1, 2-DIETHYL TETRAIODO DIALUMENE

Mol. Wt.:	Formula:	Synonyms:
619.72	$C_2H_5I_2AlAlI_2C_2H_5$	
	Characteristics: Liquid (226)	V.P.: 4158-160 (226)

Solubility:
d. H_2O (226)

Flammability:
Spontaneously flammable (226)

1, 1, 2, 2-TETRAMETHYL DIALUMENE

Mol. Wt.:	Formula:	
116.12	$(CH_3)_2HAlAlH(CH_3)_2$	
	Characteristics: Liquid - colorless (226)	B.P.: Decomposes (226)

Unique conditions, reaction products:
Reacts with H_2O to yield $CH_4 + H_2 + Al_2O_3$ (92).

Solubility:
s. organic solvents; d. H_2O (226)

Flammability:
Spontaneously flammable (92).

PENTAMETHYL DIALUMENE

Mol. Wt.:
130.14

Formula:
$(CH_3)_3Al_2H(CH_3)_2$

Synonyms:
Pentamethyl aluminum hydride

Characteristics:
Liquid (226)

B.P.:
d. air (226)

Unique conditions, reaction products:
Reacts with H_2O to yield $CH_4 + H_2 + Al_2O_3$ (92)

Flammability:
Spontaneously flammable (92).

1, 1, 1-TRIETHYL TRICHLORODIALUMENE

Mol. Wt.:
247.52

Formula:
$(C_2H_5)_3AlAlCl_3$

Synonyms:
Ethyl aluminum sesquichloride

M.P.:
-20°C (226)

Characteristics:
Liquid - yellow (226)

V.P.:
14^{90}
34^{110}
76^{130}
525^{190}
} (226)

d./sp. gr.:
1.09225 (226)

B.P.:
204°C (extrapolated) (226)

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

Mol. Wt.:
699.0 (79)

Formula:
$4Al(C_2H_5)_3 \cdot 3(C_2H_5)_2O$

Characteristics:
Liquid - colorless (79)

B.P.:
112^{16} (79)

Unique conditions, reaction products:
Explodes with moisture evolving ethane; warming evolves copious fumes of ether (195).

Solubility:
Explodes with cold H_2O (79).

Flammability:
Explodes with moisture (195).

ALUMINUM SESQUIBROMIDE ETHYLATE

Characteristics:
Liquid (125)

Unique conditions, reaction products:
Explodes with decomposition on contact with H_2O 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:
$(CH_3)_2AsCl$

Synonyms:
Dimethylarsenic monochloride
Chlorodimethyl arsine
Cacodyl chloride

M.P.:
< -45°C (79)

Characteristics:
Liquid - colorless (79)

d./sp. gr.:
1.5046_4^{12} (79)

B.P.:
109°C (79)

V.d.:
4.84 (195)

n_D^{12}
1.5203 (79)

Synthesis:
Dissolve cacodylic acid in excess HCl and reduce with solution of hypophosphorus 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 $CaCl_2$ and distilled in a Cl_2 atmosphere (176).

Solubility:
s. alcohol; i. H_2O, ether (195).

Flammability:
Spontaneously flammable (226).

CACODYL FLUORIDE

Mol. Wt.:
123.94

Formula:
$(CH_3)_2AsF$

Characteristics:
Liquid - colorless (unbearable repulsive odor) (176)

Solubility:
i. H_2O (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:
$(CH_3)_2AsI$

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 SO_2; 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 SO_2; (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 CO_2 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 CO_2 atmosphere (176).

Solubility:
i. H_2O (176); s. organic solvent (103).

Flammability:
Spontaneously flammable (227).

DIMETHYL ARSINE

Mol. Wt.:
105.99

Formula:
$(CH_3)_2AsH$

d./sp. gr.:
1.213^{29}_{29} (79)

Characteristics
Liquid - colorless (226)

V.P.:
1.213^{20} (226)
1.210^{25}

B.P.:
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). $[(CH_3)_2As]_2O + H_2 \rightarrow (CH_3)_2As\cdot As(CH_3)_2 + H_2O$; $(CH_3)_2As\cdot As(CH_3)_2 + H_2 \rightarrow 2(CH_3)_2AsH$ (176).

Solubility:
s. organic solvent (226); ∞ alcohol, ether, chloroform, carbon disulfide, acetic acid (79).

Flammability:
Spontaneously flammable (226).

CACODYL CYANIDE

Mol. Wt.:
131.01

Formula:
$(CH_3)_2AsCN$

M.P.:
33°C (79)

Characteristics
Powder - lustrous colorless (79)

B.P.:
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) $[(CH_3)_2As]_2O + 2HCN \xrightarrow{\text{distill}} 2(CH_3)_2AsCN + H_2O$ (contaminant of $[(CH_3)_2As]_2O$ hard to remove) (176)
(2) $[(CH_3)_2As]_2O + Hg(CN)_2 \rightarrow 2(CH_3)_2AsCN + Hg$ (176)
(3) $[(CH_3)_2As]_2O$ + (dry with 5 times calculated amount) HCN $\xrightarrow[\text{sealed tube}]{\Delta}$ $(CH_3)_2AsCN$ (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.:	Formula:	
245.86	$(CH_3)(C_2H_5)AsI$	
	Characteristics:	B.P.:
	Liquid - yellow oil (176)	65^{14} (176)

Synthesis:
Reflux aqueous caustic alkaline solution of ethylaliiodoarsine for a few hours with CH_3I, the solution is then neutralized, freed from alcohol, acidified with HCl and finally saturated with SO_2 (176).

Unique conditions, reaction products:
Slight decomposition on boiling (176).

Flammability:
Occasionally ignites spontaneously at ordinary temperatures (176).

ETHYL METHYL ARSINE

Mol. Wt.:	Formula:	B.P.:
119.95	$HAs(CH_3)(C_2H_5)$	71°C (52)

Flammability:
Ignites spontaneously in air (52).

ARSENIC TRIMETHYL

Mol. Wt.:	Formula:	Synonyms:
120.03	$As(CH_3)$	Trimethyl arsine
M.P.:	Characteristics:	V.d.:
-87.3°C (103)	Liquid - colorless	4.14 (195)
d./sp. gr.:	n_{Ds}^{20}	Surface tensions:
1.124^{22} (103)	1.4541 (103)	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 CO_2 (176).

Solubility:
sl. s. H_2O (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:
$(C_2H_5)AsH$

d./sp. gr.:
1.338_4^{24} (226)

Characteristics:
Liquid - colorless (226)

B.P.:
105 96.5 - 97 (226)

$\frac{n_D^{25}}{1.4709}$ (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

d./sp. gr.:
1.150^{20}_{4} (103)

B.P.:
140^{736} (sl.d.) (103)

Characteristics:
Liquid - colorless (103)

n^{20}_{Di} 1.4751 (103)

n^{25}_{Di} 1.4670 (103)

V.P.:
$15^{36.5 - 37}$ (103)

V.d.:
5.59 (195)

Surface tension:
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

M.P.:
-5°C (79)

d./sp. gr.:
1.447^{15} (79)

Formula:
$(CH_3)_2AsAs(CH_3)_2$

Characteristics:
Liquid - oily yellow (79)

B.P.:
163^{760} (79)

Synonyms:
Tetramethyl diarsine
Diarsenic tetramethyl
Dimethylarsine
Dicacodyl
Tetramethyldiarsyl

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 hypophosphorus 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 (80)

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

M.P.:
< -40°C (195)

Formula:
$[(CH_3)_2As]_2S$

Characteristics
Liquid - oily (79)

B.P.:
211°C (79)

Synonyms
Tetramethyl diarsinthiane
Bisdimethylarsine sulfide
Dicacodyl sulfide

Synthesis
(1) Pass H_2S 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. H_2O; s. alcohol, ether (79)

Flammability:
Ignites spontaneously in air (195).

TETRAMETHYL DIARSINE

Mol. Wt.:
266.07

Formula:
$(C_2H_5)_2As_2(C_2H_5)_2$

d./sp. gr.:	Characteristics	B.P.:
$1.2^{23.7}_{4}$ (226)	Liquid (226)	185°-190°C (226)

$$\frac{n^{25}_{D}}{1.6709}$$ (226)

Synthesis:

Mix sodium arsenide with four to five times its weight of quartz sand and reflux with ethyl iodide in an atmosphere of CO_2, let the reaction finish and cool; extract with ether in CO_2 atmosphere and mix extract with absolute alcohol (176).

Solubility:

i. H_2O; s. alcohol, ether (226)

Flammability:

Spontaneously flammable (226).

PHENYL CACODYL

Mol. Wt.:	Formula:	Synonyms:
458	$(C_6H_5)_2As \cdot As(C_6H_5)_2$	Tetraphenyl diarsine

M.P.:	Characteristics:
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

Mol. Wt.:	Formula:	B.P.:
110.71	$C_2H_5BCl_2$	1^{100} (207)

Synthesis:

Heat triethylborine and boron trichloride for 4 hours at 200°C (204);

$$(C_2H_5)3B + BCl_3 \rightarrow C_2H_5BCl_2 + (C_2H_5)_2BCl \quad (206\text{-}207)$$

Military and industrial uses:

Preparation of boraxoles (206-207)

Flammability:

Spontaneously flammable (204).

TRIMETHYL BORON

Mol. Wt.:
55.92

Formula:
$B(CH_3)_3$

Synonyms:
Trimethyl borine
Boron trimethyl
Boron methyl

M.P.:
$-153^{161.5}$ (226)

Characteristics:
Gas - colorless (79)

d./sp. gr.:
$.63^{100}$ (226)
1.9108

B.P.:
-20°C (226)

V.P.:
80^{-50} (226)
31^{-80}

Synthesis:
A grignard reaction of (Mg + n-butyl ether + CH_3Br) takes 6 hours for completion in an oxygen free nitrogen atmosphere, bubble nitrogen through the subsequent reaction, add BF_3 dropwise at -78°C, warm to 70°C, in 2 hours the product condenses in cold traps. Purify product by high vacuum distillation at 78°C. Trap in receiver at -124°C or substitute ethyl ether for n-butyl ether and add BF_3 in form of diethyl etherate or bubble into grignard solution as a gas. Keep H_2SO_4 present between the condenser 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

Mol. Wt.:
138.84

Formula:
$C_4H_9BCl_2$

Characteristics:
Liquid (103)

B.P.:
31^{10} (204)
88 (103)

Synthesis:
Heat 14 moles of tributylborine for 20 hours at 200°C with .31 moles of borine trichloride (204)
$(n\text{-}C_4H_9)_3B + 2BCl_3 \rightarrow 3C_4H_9BCl_2$ (208).

Solubility:
s. organic solvent; d. H_2O (103)

Flammability:
Spontaneously flammable (204).

BUTYL BORON DIFLUORIDE

Mol. Wt.:	Formula:	B.P.:
105.84	$C_4H_9BF_2$	35^{760} (204)

Synthesis:
Heat tributylborine and boron difluoride 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

Mol. Wt.:	Formula:	Synonyms:
104.40	$(C_2H_5)_2BCl$	Diethylchloroborine

M.P.:	Characteristics:	B.P.:
-84.6°C (103)	Liquid (103)	25^{100} (103)

Synthesis:
Heat triethylboron [illegible] at 200°C (204);
$2(C_2H_5)_3B + BCl_3 \rightarrow$ [illegible] (204)

Solubility:
s. organic solvents; d. H_2O (103)

Thermodynamic properties:
heat of vaporization: 7.9 kcal/mol (103)

Flammability:
Spontaneously flammable (204).

DIPROPYL CHLOROBORINE

Mol. Wt.:	Formula:	
132.45	$(C_3H_7)_2BCl$ $[C_6H_{14}BCl]$	

M.P.:	Characteristics:	B.P.:
< 125°C (226)	Liquid - colorless (226)	127°C (226

d./sp. gr.:
$.848^{20}$ (226)

Solubility:
s. organic solvents (226)

Flammability:
Spontaneously flammable (226).

TRIETHYL BORINE

Mol. Wt.:
98.00

Formula:
$B(C_2H_5)_3$

Synonyms:
Boron triethyl
Triethyl boron
Boron ethyl

M.P.:
-93°C (226)

Characteristics:
Liquid - colorless (226)

V.P.:
12.5^0 (226)

d./sp. gr.:
$.696^{20}$ (226)

n_D^{20} (226)
1.4485

Viscosity:
.30 (at 77°F) (237)

B.P.:
95°C (226)

Synthetic
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

Mol. Wt.:
160.5°C

Formula:
$(C_4H_9)_2BCl$

Synonyms:
Dibutyl chloroborine

Characteristics:
Liquid - colorless (103)

B.P.:
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:
$(C_3H_7)_3B$

M.P.:
-52.5°C (103)

Characteristics:
Liquid - colorless (195)

B.P.:
157^{20} (195)

d./sp. gr.:
.725 (195)

$n_{Ds}^{22.8}$ (79)
1.4135

Solubility:
i. H_2O; s. ether (195)

Flammability:
Spontaneously flammable (247),

PHENYL CYCLOTETRAMETHYLENE BORINE

Mol. Wt.:
144.02

Formula:
$C_6H_5B(CH_2)_4$

Characteristics:
Liquid - colorless (226)

V.P.:
11$^{85-87}$ (226)

Solubility:
s. organic solvent; d. air (226)

Flammability:
Spontaneously flammable (226).

TRI-n-BUTYLBORANE

Mol. Wt.:
182.16

Formula:
$(C_4H_9)_3B$

M.P.:
-34°C (190)

B.P.:
170^{22} (190)

V.P.:
-1^{20} (190)

d./sp. gr.:
.747^{25} (190)

n_{Ds}
1.4285 (190)

Ignition temperature:
flash point -82°F (190)

Solubility:
i. H_2O; 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:
$(B_2H_5)N(CH_3)(SiH_3)$

B.P.:
51°C (226)

M.P.:
-39.0°C (226)

Characteristics
Liquid - colorless (226)

V.P.:
82^0 (226)

Solubility:
s. organic solvents; d. H_2O, air (226)

Thermodynamic properties
heat of vaporization (at 60°C): 7716 cal/mol (226)

Flammability:
Spontaneously flammable (226).

DIMETHYLAMINOCHLORODIBORANE

Mol. Wt.:
105.11

Formula:
$(CH_3)_2NB_2H_4Cl$

Characteristics
Liquid (10)

$\frac{n^0_{D\,i}}{6.5}$ (103)

$\frac{n^{20}_{D\,i}}{18}$ (103)

Synthesis
n-methyl derivative of B_2H_7N (29)

Solubility:
s. organic solvent; d. H_2O, air (103)

Flammability:
Spontaneously flammable (29)

1, 1, 2-TRIMETHYL DIBORANE

Mol. Wt.:
69.75

Formula:
$B_2H_3(CH_3)_3$
$[(CH_3)_2BHBH_2(CH_3)]$

B.P.:
45.5°C (79)

M.P.:
-123°C (79)

Characteristics:
Liquid - colorless (79)

Solubility:
s. organic solvent; d. H_2O, 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:
$H(CH_3)_2BB(CH_3)_2H$ (See pages 181-182)

TRIETHYL DIBORANE

Mol. Wt.:
111.82

Formula:
$(C_2H_5)_3B_2H_3$

Characteristics:
Liquid - colorless (226)

V.P.:
4^0 (226)

Solubility:
s. organic solvents (226)

Flammability:
Spontaneously flammable (226)

N-METHYL N, N-BIS(DIETHYLBORINIC)IMIDE

Mol. Wt.:
166.92

Formula:
$((C_2H_5)_2B)_2NCH_3$

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.:
$.8266^{25}$ (226)

Characteristics:
Liquid - colorless (226)

n_{Ds}^{27} 1.4343 (226)

n_{Ds}^{25} 1.4323 (226)

V.P.:
2 144
10 168-169
1 133-134
(226)

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 H_2O to yield hydrogen; reacts violently with alcohol (149).

Solubility:
i. H_2O; s. hydrocarbon fuels, halogenation hydrocarbon fuels (may form extremely shock sensitive mixtures) (149)

Flammability:
Spontaneously flammable (149).

DIMETHYL BERYLLIUM

Mol. Wt.:	Formula:	B.P.:
39.09	$(CH_3)_2Be$	d. 190°C (226)
M.P.:	Characteristics	V.P.:
Sublimes 200°C (226)	Needles - white (226)	1 mm (226)
		30.5 158.6

Toxicity:
High (195)

Synthesis:
(1) $(CH_3)_2Hg + Be \rightarrow (CH_3)_2Be + Hg$ (110)
(2) $Cl_2Be[O(C_2H_5)_2]_2 + 2CH_3MgX \rightarrow (CH_3)_2Be + MgX_2 + MgCl_2$ (110)

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.:	Formula:	B.P.:
67.14	$Be(C_2H_5)_2$	(extrapolated) 194°C (226)
M.P.:	Characteristics	V.P.:
-13°C to -11°C (226)	Liquid - colorless (226)	d. 493-95 (226)

Solubility:
s. organic solvents (226)

Flammability:
Spontaneously flammable (27).

DIISOPROPYLBERYLLIUM

Mol. Wt.:	Formula:	
95.19	$Be(C_3H_7)_2$	
M.P.:	Characteristics	B.P.:
-9.5°C (103)	Liquid - colorless (103)	d. 60°C; (extrapolated) 280°C (103)

Unique conditions, reaction products:
Fumes on exposure to air but does not catch fire, explosive reaction with H_2O (42).

Solubility:
d. air, H_2O; s. organic solvents (103).

BISMUTH ETHYL CHLORIDE

Mol. Wt.:	Formula:	Characteristics
274.5	$BiHC_2H_5Cl$	Powder (195)

Flammability:
Spontaneously flammable (195).

TRIMETHYL BISMUTH

Mol. Wt.:	Formula:	Synonyms
254.10	$Bi(CH_3)_3$	Trimethylbismuthine
d./sp. gr.:	Characteristics	B.P.:
2.300^{18} (195)	Liquid - colorless (195)	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 formation (gas) +45.8 kcal/mol
heat of vaporization 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).

TRIVINYL BISMUTH

Mol. Wt.: 290.14

Formula: $(CH_2{=}CH)_3Bi$

B.P.: 158.1^{722} (242)

Solubility:
s. organic solvents; i. H_2O (242)

Flammability:
Spontaneously flammable (242).

TRIETHYL BISMUTH

Mol. Wt.: 254.09

Formula: $Bi(C_2H_5)_3$

M.P.: 107°C (52)

Characteristics: Liquid (79)

V.P.: (experimental) 79^{107} (103)

d./sp. gr.: 2.300^{18} (79)

B.P.: 110°C (79)

Solubility:
s. alcohol, ether; i. H_2O (79)

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

Mol. Wt.: 142.5

Formula: $(CH_3)_2Cd$

M.P.: -2.5°C (226)

Characteristics: Liquid - colorless (226)

B.P.: 105.5°C (226)

d./sp. gr.: $1.9846^{17.9}$ (226)

n_{Ds}^{18} / 1.58^{+9} (226)

Atomic refractions: 12.61 (226)

Solubility:
d. H_2O; s. organic solvents (226)

Thermodynamic properties:
heat of combustion: 3330 ± 20 cal/g (114)
heat of fusion: 9153 cal/mol at 18°C (226)
enthalpy of combustion: 475.7 ± 2.0 kcal/mol (114)
enthalpy of formation: (liq) 18.9 kcal/mol; (gas) 27.8 kcal/mol (114)

Flammability:
Spontaneously flammable (226).

DIETHYL CADMIUM

Mol. Wt.: 170.5

Formula: $(C_2H_5)_2Cd$

M.P.: -21°C (79)

Characteristics: Liquid - oil (79)

V.P.: 19.5^{64} (103)

d./sp. gr.: 1.6582 (79)

B.P.: 64°C (79)

n_{Ds}^{18} / 1.5680 (103)

Synthesis:
$C_2H_5Br + Mg \rightarrow C_2H_5MgBr$; $2C_2H_5MgBr + CdBr_2 \rightarrow Cd(C_2H_5)_2 + 2MgBr_2$ (80)

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 ± 5 cal/g
enthalpy of combustion: 800.0 ± .8 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:
$Co(C_{44}H_{62}O_4)_2$

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:
$Ga(CH_3)_3$

B.P.:
55.7°C (226)

M.P.:
-15.6°C (226)

Characteristics:
Liquid - colorless (226)

V.P.:
64.5[0] (226)

d./sp. gr.:
1.151 ± .00415 (120)

Synthesis:
$2Ga + 3Hg(CH_3)_2 \rightarrow 2Ga(CH_3)_3 + 3Hg$ (80)

Solubility:
d. H_2O; s. ether, ammonia (226).

Thermodynamic properties:
heat of formation: 17.6 kcal/mol (120)
mean heat of combustion ($Ga(CH_3)_3$ (liq) + CO_2 → Ga_2O_3 (crystal) + $3CO_2$ + $4\frac{1}{2}H_2O$ (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 GALLIUM

Mol. Wt.:
156.91

Formula:
$Ga(C_2H_5)_3$

M.P.:
-82.3°C (52)

Characteristics:
Liquid - colorless (79)

d./sp. gr.:
1.0576^{30} (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 DIGALLINE

Mol. Wt.:
199.58

Formula:
$(CH_3)_2GaGa(CH_3)_2$

B.P.:
172°C (extrapolated) (226)

Characteristics:
Liquid - colorless (226)

V.P.:
$.5^{0}$
500^{130} (with d.) (226)

Flammability:
Spontaneously flammable (226).

TRIMETHYL INDIUM

Mol. Wt.:
159.93

Formula:
$In(CH_3)_3$

Synonyms:
Indium methylate

M.P.:
88.4°C (226)

Characteristics:
Crystal (226)

d./sp. gr.:
1.568^{10} (226)

B.P.:
135.8°C (226)

V.P.:
7.2^{30}
72^{70} (226)

Solubility:
s. organic polymers; d. H_2O, air (226)

TRIETHYL INDIUM

Mol. Wt.:
202.40

Formula:
$(C_2H_5)_3In$

M.P.:
-32°C (226)

Characteristics:
Liquid - colorless (226)

d./sp. gr.:
1.538^{20} (226)

B.P.:
144°C (226)

Solubility:
d. H_2O, air; s. organic solvents (226)

Flammability:
Spontaneously flammable in air (226).

TRIPROPYL INDIUM

Mol. Wt.:
244.10

Formula:
$(C_3H_7)_3In$

M.P.:
-51°C (226)

Characteristics:
Liquid - colorless (226)

d./sp. gr.:
1.501^{20} (226)

B.P.:
178°C (226)

Solubility:
s. organic solvents; d. H_2O, air (226)

Flammability:
Spontaneously flammable (226).

POTASSIUM NITROMETHANE

Mol. Wt.:
99.20

Formula:
KCH_2NO_2

Unique conditions, reaction products:
Na or K salts of nitromethane exploded when dry salt was moistened with a little H_2O (143).

TETRAACETENYL NICKEL TETRAPOTASSIUM

Mol. Wt.:
276.13 (103)

Formula:
$K_4[Ni(C{\equiv}CH)_4]$

Characteristics:
Red (103)

Flammability:
Spontaneously flammable (103).

METHYL LITHIUM

Mol. Wt.:
21.96

Formula:
CH_3Li

Characteristics:
Solid (226)

Synthesis:
React lithium metal and methyl chloride in anhydrous ether or dimethyl mercury with ethyl lithium (pure product) $[2LiC_2H_5 + Hg(CH_3)_2 \rightarrow 2LiCH_3 + Hg(C_2H_5)_2]$ (184).

Flammability:
Spontaneously flammable (226).

ETHYL LITHIUM

Mol. Wt.:
36.00

Formula:
LiC_2H_5

Synonyms:
Lithium ethyl

M.P.:
95°C (103)

Characteristics:
Tablets - colorless (103)

V.P.:
$.00045^{70}$ (103)

B.P.:
sublimes (103)

Solubility:
s. organic solvents (103)

Flammability:
Spontaneously flammable (50).

N-PROPYL LITHIUM

Mol. Wt.:
50.04

Formula:
LiC_3H_7

Characteristics:
Liquid - colorless (103)

V.P.:
$.0005^{50}$ (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.:
$.0004^{60}$
$.001^{70}$ (103)

B.P.:
150°C (79)

d./sp. gr.:
.68 - .70 (190)

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.:
36.77

Formula:
$Li(CH_3)_4B$

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:
C_6H_5Li

Synthesis
(1) $(C_6H_5)_4Pb + 4C_4H_9Li \rightarrow (C_4H_9)_4Pb + 4C_6H_5Li$ (184)
(2) $(C_6H_5)_3Sb + 3C_2H_5Li \rightarrow 3C_6H_5Li + (C_2H_5)_3Sb$ (184)

Flammability:
Spontaneously flammable (50).

METHYLENE DILITHIUM

Mol. Wt.:
27.91

Formula:
$LiCH_2Li$

Characteristics
Solid - brown (226)

Solubility:
d. H_2O, air; i. alcohol (226)

Flammability:
Spontaneously flammable in air (226).

METHYLENE MAGNESIUM

Mol. Wt.:
38.35

Formula:
$MgCH_2$

Characteristics
Solid - rust colored, amorphous (226)

Synthesis

$(CH_3)_2Mg \xrightarrow{250°C} > MgCl_2$ (35)

Solubility:

d. H_2O, air; i. organic solvents (226)

Flammability:

Spontaneously flammable (34).

DIMETHYL MAGNESIUM

Mol. Wt.:
54.50

Formula:
$Mg(CH_3)_2$

M.P.:
d. 200°C (226)

Characteristics:
Solid (226)

V.P.:
$.2^{190}$ (226)

Solubility:

s. ether (226)

Flammability:

Spontaneously flammable (34)

MAGNESIUM DIETHYL

Mol. Wt.:
82.44

Formula:
$Mg(C_2H_5)_2$

M.P.:
0°C (195)

Characteristics:
Liquid (room temperature) (195)

B.P.:
d. 176°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 MAGNESIUM

Mol. 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.:
$(10^{-4}\text{-}10^{-5})^{100-130}$ (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 H_2O, aqueous bases or acids (184).

Solubility:

sl. s. CS_2, CCl_4, chloroform (slow reaction); moderately s. benzene, ether, cyclohexane; very s. pyridine, tetrahydrofluoride (184)

Thermodynamic properties:

heat of fusion: 6.3 kcal/mol
specific conductivity: 1.4×10^{-5} (NH_3) (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.:	Formula:
83.3	$NaCH_2NO_2$

Unique conditions, reaction products:

Na or K salts of nitromethane exploded when dry salt was moistened with a little H_2O (143).

METHYL SODIUM

Mol. Wt.:	Formula:
38.00	CH_3Na
M.P.:	Characteristics:
200°C (226)	Solid (226)

Solubility:

i. organic; d. air, H_2O (226)

Flammability:

Spontaneously flammable (226).

SODIUM METHYLATE

Mol. Wt.:
54.03

Formula:
CH_3ONa

d./sp. gr.:
4.6 lbs/gal (132)

Characteristics:
Powder - white (132).

Solubility:
d. H_2O (132).

Military and industrial uses:
Organic synthesis (132)

Flammability:
Spontaneously flammable in moist air (143).

SODIUM ACETATE

Mol. Wt.:
82.03

Formula:
$CH_3C(O)ONa$

M.P.:
324°C (195)

Characteristics:
Crystal - white (195)

d./sp. gr.:
1.528 (195)

n_D^t (79)
1.464

Solubility:
sl. s. alcohol; s. H_2O, organic polymers; i. organic solvents (79)

Military and industrial uses:
Buffer in photography, mordant in dyeing (132).

Flammability:
Possible spontaneous flammability in moist air or H_2O (27)

ETHYL SODIUM

Mol. Wt.:
52.06

Formula:
NaC_2H_5

M.P.:
Decomposes (226)

Characteristics:
Crystal - white (226)

Solubility:
d. H_2O, 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.:
1.75^{0} (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./gp. 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:
$P(CH_3)_3$

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 PCl_3 and CH_3MgBr and di-n-butyl ether, then distill phosphine quietly from the mixture in dry N_2 atmosphere following distillation of the ether; use of dry-oxygen-free atmosphere in preparation is essential (246)

Solubility:
i. H_2O; 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:
$(C_2H_5)_2PH$

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^{20}	Characteristics	B.P.:
1.3248 (79)	Liquid - colorless (79)	48°C (79)

Solubility:
s. organic polymers; i. H_2O (103).

Flammability:
Spontaneously flammable (79)

TRIS--TRIFLUOROMETHYL PHOSPHINE

Mol. Wt.:	Formula:	
238.01 (226)	$(CF_3)_3P$	
	Characteristics	B.P.:
	Liquid - colorless (226)	17.3°C (22)

Solubility:
d. H_2O; s. organic polymers (226)

Thermodynamic properties.
heat of vaporization: 5890 cal/mol (226)

Flammability:
Spontaneously flammable (79)

TRIBUTYL PHOSPHINE

Mol. Wt.:	Formula:	
202.32	$P(C_4H_9)_3$	
F.P.:	B.P.:	V.P.:
-60° to-65°C (190)	245°C (190)	50^{126} (103)
d./sp. gr.:	n_D^{25}	
$.8100_4^{25}$ (190)	1.4588 (190)	

Ignition temperature:
flash point: 40°C
fire point: 43°C
auto-ignition temperature: 260°C
} (190)

Solubility:
Almost i. H_2O; 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:
$(C_2H_5)_2PO(C_2H_5)(OC_2H_5)$

V.P.:
1^{91-93} (103)

d./sp. gr.:
1.0004^{20} (103)

Characteristics:
Liquid - colorless (103)

n_D^{20}
1.4868 (103)

Solubility:
s. organic; d. H_2O; air (103)

Flammability:
Spontaneously flammable (103)

ANTIMONY TRIMETHYL

Mol. Wt.:
166.86

Formula:
$(CH_3)_3Sb$

Synonyms:
Trimethyl stibine

M.P.:
-87.6°C (103)

Characteristics:
Liquid (195)

d./sp. gr.:
1.523^{15} (79)

B.P.:
80.6°C (79)

Unique conditions, reaction products:
Reacts vigorously with oxidizing materials (195).

Solubility:
sl. s. cold and hot H_2O; 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
} (103)

heat of combustion: 4172 ± 18 cal/g
enthalpy of combustion: 693.0 ± 31 kcal/mol
enthalpy of formation (liq): -1.4 kcal/mol
} (114)

Flammability:
Spontaneously flammable in air (195)

TRIMETHYL ANTIMONY SULFATE

Mol. Wt.:
262.85

Formula:
$(CH_3)_3SbSO_4$

Flammability:
Spontaneously flammable in air (14).

TRIVINYL STIBINE

Mol. Wt.: 202.90

Formula: $(CH_2{:}CH)_3Sb$

Characteristics: Liquid - colorless (103)

B.P.: 149.9^{722} (103)

Solubility:
s. organic solvents (241)

Flammability:
Spontaneously flammable (241)

ANTIMONY TRIETHYL

Mol. Wt.: 208.94

Formula: $Sb(C_2H_5)_3$

Synonyms: Triethyl stibine

M.P.: < -29°C (79)

Characteristics: Liquid (79)

B.P.: 159.5°C (79)

d./sp. gr.: 1.324^{16} (79)

$\frac{n_D^{15}}{1.42}$ (79)

Solubility:
i. H_2O; s. alcohol, ether (79)

Thermodynamic properties:
heat of combustion: 5552 ± 6 cal/g
enthalpy of combustion: 1162.6 ± 1.2 kcal/mol
enthalpy of formation: (liq) 2.3 kcal/mol; (gas) 13.1 kcal/mol
} (114)

Flammability:
Spontaneously flammable (195).

TRIETHYL ANTIMONY SULFATE

Mol. Wt.: 304.88

Formula: $Sb(C_2H_5)_3SO_4$

Flammability:
Spontaneously flammable in air (14).

PHENYLDIMETHYL ANTIMONY

Mol. Wt.:
228.93

Formula:
$C_6H_5Sb(CH_3)_2$

Characteristics
Liquid - colorless oil (79)

B.P.:
112^{15-18} (79)

Flammability:
Fumes in air (79)

TRIPROPYL ANTIMONY

Mol. Wt.:
250.85

Formula:
$Sb(C_3H_7)_3$

M.P.:
80-81°C (50)

Flammability:
Ignites or carbonizes on filter paper (52).

TETRAMETHYL DISTIBINE

Mol. Wt.:
303.56

Formula:
$(CH_3)_2SbSb(CH_3)_2$

M.P.:
175°C (37)

V.P.:
18^{100} (37)

Synthesis
Reaction of methyl radicals (from tetramethyl lead by pyrolysis) and an antimony mirror (37).

Flammability:
Spontaneously flammable (37)

BIS-DIMETHYLSTIBINE OXIDE

Mol. Wt.:
319.56

Formula:
$[(CH_3)_2Sb]_2O$

Synthesis
Hydrolysis $(CH_3)_2SbBr$ with alkali (36)

Flammability:
Spontaneously flammable (36)

METHYL TRICHLORO SILANE

Mol. Wt.:
149.50

Formula:
CH_3SiCl_3

M.P.:
-77.8°C (103)

d./sp. gr.:
1.273^{25}_{25} (103)

Characteristics
Liquid - colorless (acrid odor) (103)

B.P.:
66.4°C (103)

$n^{25}_{D_5}$ (103)
1.415

V.P.:
10^{-27} (103)
60^{3}

Viscosity:
.37 cs (at 25°C) (103)

Unique conditions, reaction products:
Evolves white fumes with moist air; violent reaction with H_2O yields heat and white acrid fumes) (54)

Ignition temperature:
flash point 48°f
autoignition temperature: 410°C } (103)

Solubility:
s. organic solvents; d. H_2O, 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

Mol. Wt.:
161.51

Formula:
$SiC_2H_3Cl_3$

M.P.:
-95°C

d./sp. gr.:
1.264^{25}
1.265^{20} (103)

Viscosity:
.50 cs (at 25°C) (103)

Characteristics
Liquid - colorless (acrid odor) (103)

B.P.:
91°-93°C (103)

V.P.:
10^{-11}
60^{23} } (103)
100^{34}

$n^{25}_{D_5}$
1.432 (103)

$n^{20}_{D_5}$
1.4365 (103)

Unique conditions, reaction products:
Evolves white fumes with moist air; violent reaction with H_2O (yield heat and white acrid fumes)(54).

Ignition temperature:
flash point: 70°F (103)

Solubility:
s. organic solvents; d. H_2O, alcohol (103)

Thermodynamic properties:
coefficient of expansion: .0016/°C
heat of vaporization: 88 Btu/lb
specific heat: .20
} (103)

ETHYL TRICHLOROSILANE

Mol. Wt.:
163.51

Formula:
$C_2H_5SiCl_3$

M.P.:
-105.6°C (184)

Characteristics:
Liquid - colorless (acrid odor) (103)

Viscosity:
.48 *cs* (at 25°C) (103)

d./sp. gr.:
1.238^{20}_{4} (103)

B.P.:
$97\text{-}103^{760}$ (103)

n^{20}_{D}:
1.4257 (103)

Unique conditions, reaction products:
Evolves white fumes with moist air; violent reaction with H_2O (yields heat and white acrid fumes) (54).

Ignition temperature:
flash point: 80°F (103)

Solubility:
d. H_2O, alcohol (103)

Thermodynamic properties:
heat of vaporization: 99 Btu/lb
coefficient of expansion: .0015/°C
(103)

DIMETHYL DICHLOROSILANE

Mol. Wt.:
129.07

Formula:
$(CH_3)_2SiCl_2$

M.P.:
-76°C (103)

Characteristics:
Liquid - colorless (acrid odor) (103)

V.P.:
10^{-25}
606.5
(103)

d./ sp. gr.:
1.070^{25}_{25} (103)

B.P.:
78.5°C (103)

Viscosity:
.47 cs (at 25°C) (103)

n_D^{25}
1.405 (103)

Unique conditions, reaction products:
Evolves white fumes with moist air; violent reaction with H_2O (yields heat and white acrid fumes) (54).

Ignition temperature:
autoignition temperature: 410°C
flash point: 15°F (103)

Solubility:
s. organic solvents; d. H_2O, alcohol (103).

Thermodynamic properties:
heat of vaporization: 99.4 Btu/lb
surface tension: 20.1 dynes/cm
coefficient of expansion: .0013/°C } (103)

TRIMETHYL CHLOROSILANE

Mol. Wt.:
108.65

Formula:
$(CH_3)_3SiCl$

M.P.:
-57.7°C (103)

Characteristics:
Liquid - colorless
(acrid odor) (103)

V.P.:
10^{-34}
60^{-4}
100^{6}
$400^{39.4}$ } (103)

d./sp. gr.:
$.854^{25}_{25}$
$.846^{25}_{4}$ (103)

B.P.:
57.9°C (103)

n_D^{20}
1.3884 (103)

Viscosity:
.47 cs(at 25°C) (103)

Surface tension:
9.5 dynes/cm (at 20°C) (103)

Unique conditions, reaction:
Evolves white fumes with moist air; violent reaction with H_2O (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

Mol. Wt.:
74.20

Formula:
$Si(C_3H_7)H_3$

d./sp. gr.:
$.643 4^{20}_{4}$ (103)

Characteristics:
Liquid - colorless (103)

n^{20}_{D}
1.3759 (103)

B.P.:
23°C (103)

Solubility:
s. organic solvents; i. H_2O (103)

Thermodynamic properties:
heat of combustion: 19,000 Btu/lb (202)

Flammability:
Spontaneously flammable (103).

DIETHYL DICHLOROSILANE

Mol. Wt.:
157.13

Formula:
$(C_2H_5)_2SiCl_2$

M.P.:
-96.5°C (184)

Characteristics:
Liquid - colorless (103)

V.P.:
100^{69}
10^{21} (103)

d./sp. gr.:
1.0504^{20}_{4} (79)

B.P.:
129°C (79)

n^{20}_{D}
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 H_2O; s. ether (79)

TETRAMETHYL SILANE

Mol. Wt.:
88.23

Formula:
$(CH_3)_4Si$

M.P.:
α -101.7°C
β -99.5°C (226)

Characteristics:
Liquid - colorless (226)

n^{20}_{D}
1.3582 (226)

B.P.:
26.2°C (226)

d./sp. gr.:
$.6688^{0}_{c}$
$.6480^{20}_{4}$ (226)

Solubility:
s. organic solvents; i. H_2O (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 } (226)
heat of combustion: -920 kcal/mol

Flammability:
Spontaneously flammable (226).

AMYL TRICHLOROSILANE

Mol. Wt.:
205.60

Formula:
$SiC_5H_{11}Cl_3$

d./sp. gr.:
1.137^{25}_{25} (103)

Characteristics:
Liquid - colorless (103)

V.P.:
120^{107} (103)

n^{25}_{D}: (103)
1.4415

B.P.:
166°-169°C (103)

Viscosity:
1.10 cs (at 25°C) (103)

n^{20}_{D}: (103)
1.445

Unique conditions, reaction products:
Fumes strongly in moist air (54).

Ignition temperatures:
flash point: 135°F (103)

Solubility:
s. organic solvents; d. H_2O (103)

Thermodynamic properties
specific heat: .35
coefficient of expansion: .0014/°C (103)

BENZYL SILANE

Mol. Wt.:
122.25

Formula:
$C_6H_5 \cdot CH_2SiH_3$

n^{25}_{D}: (103)
1.505

Characteristics:
Liquid - colorless (103)

V.P.:
30^{53} (103)

Solubility:
i. H_2O; s. organic solvents (103)

Thermodynamic properties
heat of combustion: 19,000 Btu/lb (202)

Flammability:
Spontaneously flammable (202)

DIETHOXY SILOXENE

Mol. Wt.:
226.43

Formula:
$(C_2H_5O)_2$ SiOSiH_2O

Solubility:
d. H_2O (103)

Flammability:
Spontaneously flammable (103)

BIS(ETHYLAMINO) SILOXENE

Mol. Wt.:
280.57

Formula:
$[(C_2H_5)_2N]_2$SiOSiH_2OSiH_2O

Characteristics
Solid - orange (226)

Solubility:
d. H_2O, air (226)

Flammability:
Spontaneously flammable (226).

TRISTRIMETHYL SILYL PHOSPHINE

Mol. Wt.:
250.33

Formula:
$((CH_3)_3Si)_3P$

Characteristics
Liquid (157)

B.P.:
253°C (157)

Synthesis
React $NaPH_2$ and $(CH_3)_3SiCl$ in an ether solvent at room temperature and distill in a spinning band column (157).

Flammability:
Spontaneously flammable (157).

TRIETHYL TELLURIUM

Mol. Wt.:
214.67

Formula:
$Te(C_2H_5)_3$

M.P.:
138°C (52)

Characteristics:
Liquid - reddish yellow (52)

Flammability:
Spontaneously flammable in air (52).

ISOBUTYL TITANIUM TRICHLORIDE

Mol. Wt.:
211.29

Formula:
$i\text{-}C_4H_9TiCl_3$

Characteristics:
Solid (128)

Flammability:
Nearly pyrophoric (128).

TRIMETHYL THALLIUM

Mol. Wt.:
249.38

Formula:
$(CH_3)_3Tl$

M.P.:
38.5°C (226)

Characteristics:
Needles - colorless (226)

V.P.:
520 (226).

B.P.:
147°C (extrapolated) (226).

Solubility:
d. light, H_2O; s. organic solvent (226).

Flammability:
Spontaneously flammable (226).

PHENYL DICYCLOPENTADIENYLVANADIUM

Mol. Wt.:
258.11

Formula:
$(C_5H_5)_2VC_6H_5$

Flammability:
Spontaneously flammable in air (243)

TRIPHENYL TUNGSTEN-TRIS(PHENYL LITHIUM)-TRIS(DIETHYL ETHER)

Mol. Wt.:
875.81

Formula:
$(C_6H_5)_3W \cdot 3LiC_6H_5 \cdot 3(C_2H_5)_2O$

Characteristics:
Violet (226)

Solubility:
s. organic solvent; d. H_2O, alcohol (226).

Flammability:
Spontaneously flammable (226).

ZINC DIMETHYL

Mol. Wt.:
95.45

Formula:
$Zn(CH_3)_2$

M.P.:
-42°C (224)

Characteristics:
Liquid - colorless (226)

V.P.:
124^0 (226).

d./sp. gr.:
1.386^{10} (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).

DIVINYLZINC

Mol. Wt.:
119.42

Formula:
$(CH_2{:}CH)_2Zn$

B.P.:
32^{22} (241)

Unique conditions, reaction products:
Yield ethylene on contact with H_2O (241).

Synthesis:
$ZnCl_2 + 2CH_2{:}CHMgBr \xrightarrow{(CH_3)_2O} (CH_2{:}CH)_2Zn + 2MgBrCl$ (241)

Flammability:
Spontaneously flammable in air (241).

ZINC ISOBUTYL

Mol. Wt.:
179.6

Formula:
$i\text{-}CH_3(CH_2)_3Zn$

Unique conditions, reaction products:
Reacts with H_2O to yield ethane (27).

Flammability:
Spontaneously flammable (27).

DIETHYL ZINC

Mol. Wt.:
123.50

Formula:
$Zn(C_2H_5)_2$

M.P.:
-30°C (226)

Characteristics:
Liquid - colorless (226)

V.P.:
27^{30} (226)

d./sp. gr.:
1.182^{18} (226)

B.P.:
117.6°C (226)

n_D^s
1.4936 (226)

Toxicity:
When burning, yields zinc oxide fumes (threshold value 5 mg/m^3) (142).

Synthesis:
$Zn + C_2H_5I \rightarrow C_2H_5ZnI$ (2) $\rightarrow Zn(C_2H_5)_2 + ZnI_2$ (80)

Unique conditions, reaction products:
Extremely violent decomposition in H_2O to yields $Zn(OH)_2 + C_2H_5$ (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-$CH_3(CH_2)_4Zn$

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:
$Zn(C_3H_7)_2$

d./sp. gr.:
1.1034_4^{20} (226)

Characteristics:
Liquid (226)

V.P.:
$10^{4.8}$ (226)

B.P.:
160°C (226)

$n_D^{18.6}$
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:
$(H(CH_3)_2BB(CH_3)_2H)$

M.P.:
-73°C (103)

Characteristics:
Liquid (103)

B.P.:
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)

(b) HALIDES

DI-CHLOROACETYLENE

Mol. Wt.:	Formula:	Synonyms:
94.93	ClC:CCl	Dichloroethyne
M.P.:	Characteristics:	B.P.:
-66°C (79)	Gas (123)	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).

HEXACHLOROETHANE MIXTURE

Mol. Wt.:	Formula:	Synonyms:
236.76	CCl_3CCl_3	Perchloroethane Carbon hexachloride
M.P.:	Characteristics:	Carbon trichloride
186.6°C (sublimes) (132)	Solid - rhombic, triclinic or cubic crystals, colorless, camphor-like odor (132)	Smoke powder
d./sp. gr.:		V.P.:
2.091 (132)		$1^{32.7}$ (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

Mol. Wt.:	Formula:	Synonyms:
104.9	HC:CBr	Bromacetylene Bromoacetylene Ethynyl chloride

d./sp. gr.:
.0047 (79)

Characteristics:
Gas (79)

V.d.:
4.684 g/cm^3 (195)

B.P.:
4°C (79)
-2°C (195)

Solubility:
s. ether, dilute HNO_3, dilute HCl (79)

Flammability:
Spontaneously flammable in air (195)

CHLOROACETYLENE

Mol. Wt.:
60.48

Formula:
HCl 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 O_3 and glows in the dark (46).

Solubility:
d. H_2O; s. alcohol (79)

Flammability:
Unstable, spontaneously flammable (123).

ACETYL BROMIDE

Mol. Wt.:
122.95

Formula:
CH_3COBr

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)

d./sp. gr.:
1.66316^{16}_{4} (79)

n^{16}_{D}
1.4538 (79)

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

Mol. Wt.:
78.50

Formula:
CH_3COCl

Synonyms:
Ethanoyl chloride
Acetic acid chloride

M.P.:
-112°C (79)

Characteristics:
Liquid - colorless, fuming (79)

V.d.:
2.7 (195)

d./sp. gr.:
1.1039^{21}_{4} (79)

B.P.:
51°-52°C (79)

n^{20}_{D} (79)
1.3898

Toxicity:
High as irritant, on ingestion, and inhalation; when heated emits highly toxic fumes of phosgene (195).

Synthesis
$CH_3COOH + PCl_3 \rightarrow C_2H_3ClO + HCl\uparrow$ (190)
(distill)

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:
C_6H_5COCl

M.P.:
-1°C (46)

Characteristics:
Liquid - colorless - fuming (46)

B.P.:
197°C
194^{742} (46)

d./sp. gr.:
1.2187^{15}_{15} (36)

$\frac{n^{20}_{D}}{1.55369}$ (46)

Unique conditions, reaction products:
Smokes in air (191), gives benzoyl derivatives with alcohols, phenols and amines (46).

Solubility:
s. C_6H_6, ether (191)

ANISOYL CHLORIDE

Mol. Wt.:
170.5

Formula:
$CH_3OC_6H_4COCl$

Synonyms:
Anisic acid chloride

M.P.:
22°C (46)

B.P.:
$160-164^{55}$ (46)

Toxicity:
High (acute local irritant) on ingestion and on inhalation (195).

Unique conditions, reaction products:
Hydrolyzes to HCl with H_2O (195).

Solubility:
i. H_2O; 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:
CH_3NHNH_2

M.P.:
-62.5°F (149)

d./sp. gr.:
7.32 (at 68°F) (149)

Viscosity:
.85 (at 68°F) (149)

Characteristics:
Liquid - clear, water-white, ammoniacal odor (149)

B.P.:
189.5°F (149)

V.P.:
.31 40°F
1.0 80°F
3.1 120°F
7.9 160°F
(149)

n_D:
1.59 (149)

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 CO_2 and/or O_2 in air, hypergolic with H_2O_2, N_2O_4, F_2, HNO_3 (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 H_2O, 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 O_2" (149).

PRODUCTS OF NITRATION OF DINITROFLUOROETHANE

Unique conditions, reaction products:
Air admitted into vacuum at 60°C explosive reaction (9).

ETHYL NITRITE

Mol. Wt.:	Formula:	Synonyms:
75.07	$C_2H_5NO_2$	Nitrous ether
d./sp. gr.:	**B.P.:**	**V.d.:**
.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

Mol. Wt.:	Formula:	n_{Da} (46)
60.1 (195)	$(CH_3)_2NNH_2$	1.40753
M.P.:	**Characteristics**	**V.P.:**
-58°C (195)	Liquid - ammoniacal odor (46)	157^{25} (195)
d./sp. gr.:		
.782 (195)	**B.P.:**	**Viscosity:**
	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 temperatures:
flash point: 34°F (195)
autoignition temperature: 145.9°F (127)

Solubility:
s. H_2O, ethanol, $(C_2H_5)_2O$ (46); completely miscible with H_2O, hydrazine, diethyl triamine, C_2H_5OH 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)
} (1)

Military of 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

Mol. Wt.:
50.1

Formula:
HC≡CC≡CH

Synonyms:
Butadiyne
Butadiene

M.P.:
-36.4°C (195)

B.P.:
10.3°C (195)

n_{D}^{α} (46)
1.43862

d./sp. gr.:
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

Mol. Wt.:
118.1

Formula:
$(CH_3CO)_2O_2$

Synonyms:
Ethanoyl peroxide
Diacetyl peroxide

M.P.:
30°C (195)

Characteristics
Solid - crystal - colorless (195)

B.P.:
63^{21} (195)

d./sp. gr.:
1.18 (195)

V.d.:
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. H_2O, alcohol, ether; d. NaOH, CCl_4 (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:
C_6H_4OHNO

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. H_2O (190)

Thermodynamic properties:
heat of combustion: 715.5 cal (46)

Flammability:
Impure - explodes by self-ignition (190)

PHENYLDIAZOSULFIDE

Mol. Wt.:
138.12

Formula:
C_6H_5NNSH

Characteristics:
Solid - red (163)

Unique conditions, reaction products
Explodes when dried in air (163)

STYRENE OXIDE

Mol. Wt.:
120.15

Formula:
C_8H_8O

Synonyms:
Phenyloxiran
Benzene, 1, 2epoxylethyl

d./sp. gr.:
1.0523^{16}_{4} (79)

Characteristics:
Liquid (79)

B.P.:
381.6°F (129)

Ignition temperature:
flash point 175°F
autoignition temperature: 175°F } (129)

Solubility:
i. H_2O; s. alcohol, ether (79)

2-ETHYLHEXALDEHYDE

Mol. Wt.:
128.21

Formula:
$CH_3(CH_2)_3CH(C_2H_5)CHO$

Synonyms:
2-ethyl hexanal

M.P.:
< -100°C (79)

Characteristics:
Liquid (195)

V.P.:
1.8^{20} (195)

d./sp. gr.:
.8205 (195)

B.P.:
163760 (79)

V.d.:
4.42 (195)

Ignition temperature:
flash point (open cup): 125°F (195)

Solubility:
i. H_2O; s. alcohol, ether (79)

Flammability:
Spontaneously flammable in air (217)

STEARIC ACID

Mol. Wt.:
284.49

Formula:
$CH_3(CH_2)_{16}CO_2H$

Synonyms:
Octadecanoic acid

M.P.:
70.1°C (79)

Characteristics:
Solid -monoclinic leaf (79)

n_D^{30}
1.4299 (79)

d./sp. gr.:
$.9408_4^{20}$ (79)

B.P.:
183.5°C (79)

Unique conditions, reaction products:
Heats spontaneously (129)

Ignition temperatures:
flash point 385°F
autoignition temperature: 743°F (129)

Solubility:
i. H_2O; *o°* alcohol, ether, acetone, C_6H_6; s. chloroform, CCl_4, CS_2 (79)

TRIDECYL ALDEHYDE

Mol. Wt.:
198.35

Formula:
$CH_3.[CH_2]_{11}CHO$

Synonyms:
Tridecanal

M.P.:
14°C (46)

B.P.:
$126\text{-}128^{10}$ (46)

n_D^{18}
1.4384 (46)

d./sp. gr.:
$.8356_4^{18}$ (46)

Solubility:
i. H_2O; 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 O_2 and moisture (127)

O, O DIMETHYL THIOPHOSPHORYL CHLORIDE

Characteristics:
Liquid (127)

Unique conditions, reaction products
Unstable above 30-40°C, fumes, may explode at 100°C (127)

Ignition temperatures
autoignition temperature: 212°F (127)

3 PYRIDINE-DIAZONIUM FLUOROBORATE

Flammability:
When completely dry - violent spontaneous decomposition (47)

PYRIDINIUM PERCHLORATE

Formula:
$C_5H_5N \cdot HClO_4$

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 H_2O (3)

Trimethyl Amine and Lithium Aluminum Hydride Addition Compound

Synthesis:
Excess trimethyl amine reacts with an ethereal solution of $LiAlH_4$ in vacuo at -57°C to yield a white addition compound (163)

Solubility:
sl. s. ethane; i. C_6H_6 (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).

PSC-H Polymer

Synthesis:
PSC-H at temperatures over -124°C forms extremely pyrophoric polymers (240).

$C_2Cl_6 + Zn$

Flammability:
With moisture spontaneous heating and ignition may occur (63).

Tributyl Boron and Benzenediazonium Chloride Reaction Products

Synthesis:
Heat .14 moles tributyl borine with .31 moles benzenediazonium chloride at 200°C for 4 hours and 300°C for 1 hour. Reaction yields low boiling gases and a pyrophoric mixture of products boiling between 20° and 100°C (203)

C_6H_5HgCl and $CrCl_3 \cdot THF$ Reaction Products

Synthesis

Heat $3C_6H_5HgCl + CrCl_3 \cdot 3THF$ at: (1) Atmospheric pressure and temperatures greater than 60°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-arene-complexes (244)

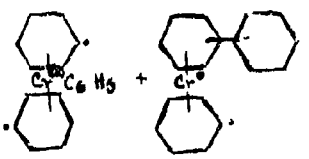
Flammability:

Spontaneously flammable (244).

Structures

Black solid considered to be composed of approximately equal parts of bis-benzene- and benzene-biphenyl-chromium intermediates possible structures

$$(C_6H_5)_3Cr(III) \longrightarrow$$



(244)

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°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).

Zinc and Iodine
(equal amounts)

Flammability:
Spontaneously flammable in H_2O (3).

Magnesium and Iodine
(equal amounts)

Flammability:
Spontaneously inflames with H_2O (3).

Rosin

M.P.:
100-150°C (195)

d./sp. gr.:
1.08^{25} (195)

Formula:
80-90% abiatic acid
5.6% anhydride

Synonyms:
Pisc. resin
Colophony
Gum rosin

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).

Unique conditions, reaction products:
Can react with oxidizing materials (195).

Ignition temperature:
flash point 370°F. (195)

Solubility:
s. alcohol, ether, C_6H_6, glacial acetic acid, many oils, and aqueous alkaline solvents; i. H_2O (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 resinates 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

$Ni/MgC_2O_4 \cdot 2H_2O \xrightarrow{H_2} Ni/MgC_2O_4$ (80).

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).

$Si_2Cl_2 + NH_3$ Reaction products

Synthesis

React $Si_3Cl_6 + NH_3 \longrightarrow$ ... (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).

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).

BIBLIOGRAPHY

1. Autonutronics, Newport Beach, Calif.
   TOXIC HAZARDS OF ROCKET PROPELLANTS, by J. J. Oslake, S. Dobrin and R. A. Romine. Tech. Rept. U-108:99, Nov. 30, 1960. Table 4.2-1. AD 253236

2. Aerospace Technical Intelligence Center, Wright-Patterson Air Force Base, Ohio.
   METHODS FOR THE PREPARATION OF DIBORANE. Nov. 4, 1960, p.9. (Translation no. MCL-741 from German patent no. 1076103, p. 3, Feb. 25, 1960) AD 256193

3. Antelman, M.
   LECTURE DEMONSTRATIONS OF INCENDIARIES. Jour. Chem. Education, 30(3): 134, 1953.

4. Antelman, M.
   LECTURE DEMONSTRATIONS OF INCENDIARIES, PART 2. Jour. Chem. Education, 32(5): 274, 1955.

5. Armed Services Explosives Safety Board, Washington, D. C.
   EXPLOSIVES ACCIDENT/INCIDENT ABSTRACTS. Sept. 1961-June 1967, Oct. 1967. AD 660020
   ASESB Explosive Incident Rept. no. 23

6. Ibid. ASESB Explosive Incident Rept. no. 25

7. Ibid. ASESB Explosive Incident Rept. no. 44

8. Ibid. ASESB Explosive Incident Rept. no. 47

9. Ibid. ASESB Explosive Incident Rept. no. 59

10. Ibid. ASESB Explosive Incident Rept. no. 85

11. Association of Casualty and Surety Companies, Accident Prevention Dept., New York.
    THORIUM: ITS COMPOUNDS AND ALLOYS. Chemical Hazards Information Series, no. C-72, Dec. 1958. 24p.

12. Association of Casualty and Surety Companies, Accident Prevention Dept., New York.
    URANIUM AND ITS COMPOUNDS. Chemical Hazards Information Series, no. C-69, Feb. 1958. 23p.

13. Aubry, J. and G. Monnier
    THE PREPARATORY OF SOME METALLIC ALUMINOHYDRIDES. Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences (Gouthier-Villars) 238: 2534-2535, 1954. (CA 49:766e)

14. Bahme, C. W.
    FIRE PROTECTION FOR CHEMICALS. Boston, Mass., National Fire Protection, 1956. p.25.

15. Ibid. p. 95

16. Batha, H. D., C. D. Good and J. F. Faust
REACTION OF SODIUM HYDRIDE WITH BORON TRICHLORIDE TO FORM DIBORANE. Journal of Applied Chemistry (London), 14(6): 259, 1964.

17. Battelle Memorial Inst., Columbus, Ohio.
A STUDY OF THE TITANIUM-LIQUID OXYGEN PYROPHORIC REACTION, by J. D. Jackson, P. D. Miller and others. WADD Tech. rept. 60-258, June 1960, p. 10. AD 243554

18. Bebie, J.
MANUAL OF EXPLOSIVES, MILITARY PYROTECHNICS AND CHEMICAL WARFARE. New York, MacMillan Co., 1943, p. 123.

19. Ibid. p. 148

20. Ibid. p. 149

21. BORAX TO BORANES.
Int Advances in Chemistry Series No. 32. Ed. by R. F. Gould. Washington, D. C., American Chemical Society, 1961: 67.

22. Brokaw, R. S., E. J. Bodin and R. N. Pease
WALL EFFECTS IN THE OXIDATION OF BORON TRIETHYL VAPOR. IGNITION OF n-BUTANE. Jour. Amer. Chem. Soc., 70: 1921, 1948.

23. Brophy, L. P., W. D. Miles and R. C. Cochrane
THE CHEMICAL WARFARE SERVICE: FROM LABORATORY TO FIELD. Washington, D. C., Dept. of the Army, Office of the Chief of Military History, 1959, p. 196.

24. Ibid. p. 204

25. Ibid. p. 208

26. Ibid. p. 215

27. Bureau of Fire Prevention, City of Los Angeles, Los Angeles, Calif.
DANGEROUS CHEMICALS CODE. Los Angeles, Calif., Parker and Co., 1951.

28. Bureau of Mines, Dept. of the Interior, Pittsburgh, Pa.
REVIEW OF FIRE AND EXPLOSION HAZARDS OF FLIGHT VEHICLES. COMBUSTIBLES, by R. W. Van Dolah, M. G. Zabetakis and others. Annual rept. ASD-TR-61-278, Apr. 1960-Apr. 1961, Apr. 1961, p. 37-38. AD 262989

29. Burg, A. B. and C. L. Randolph, Jr.
THE N-METHYL DERIVATIVES OF B_2H_7N. Jour. Amer. Chem. Soc., 71: 3451-3455, 1949.

30. Burg, A. B. and C. L. Randolph, Jr.
DISPROPORTIONATION REACTIONS OF THE DIMETHYLAMINOBORON HYDRIDES Jour. Amer. Chem. Soc., 73: 953-1951. AD 5383

31. California Univ., Livermore
SOME PHYSICAL PROPERTIES OF THE HYDRIDES, by R. E. Elson, H. C. Horning and others. U. C. R. L.-4519. June 1956. p.6. AD 111696

32. Ibid. p. 9

33. Ibid. p. 12

34. Coates, G. E.
ORGANO-METALLIC COMPOUNDS. New York, John Wiley and Sons, Inc., 1956. p. 29.

35. Ibid. p. 79

36. Ibid. p. 155

37. Ibid. p. 156

38. Ibid. p. 158

39. Ibid p. 161

40. Ibid. p. 172

41. Ibid. p. 173

42. Coates, G. E. and F. Glocking
DIISOPROPYLBERYLLIUM AND SOME BERYLLIUM HYDRIDES. Journal of the Chemical Society (London), 106: 22, 1954.

43. Danner, P. S.
PREPARATION OF VERY PURE BARIUM AND STRONTIUM. Jour. Amer. Chem. Soc., 46: 2382-2384, 1924. AD 3542

44. Davis, H. M.
FIREBRAND METALS. Chemistry, 30(9): 4, 1956.

45. Davis, W. D., L. S. Mason and G. Stegeman
THE HEATS OF FORMATION OF SODIUM BOROHYDRIDE, LITHIUM BOROHYDRIDE, AND LITHIUM ALUMINUM HYDRIDE. Jour. Amer. Chem. Soc., 71(8): 2778, 1949.

46. DICTIONARY OF ORGANIC COMPOUNDS.
Ed. by J. R. A. Pollock and R. Stevens. New York, Oxford University Press, 1965.

47. Doak, G. O. and L. D. Freedman
DIAZONIUM FLUOROBORATE. Chem. and Eng. News, 45(53): 8, 1967.

48. Dreisback, R. R.
PHYSICAL PROPERTIES OF CHEMICAL COMPOUNDS III. Advances in Chemistry Series no. 29. Washington, D. C. American Chemical Society, 1961, p. 93-94.

49. Edwards Air Force Base, Calif.
A STUDY OF PENTABORANE, by A. V. Jensen and B. B. Goshgarian. AFFTC-TR-61-34. May 1961, p.2. AD 258885

50. Ellern, H.
MODERN PYROTECHNICS. New York, Chemical Publishing Co., Inc., 1961.

51. Ellern, H.
MILITARY AND CIVILIAN PYROTECHNICS. New York, Chemical Publishing Co., Inc., 1968. p.22

52. Ibid. p. 24-25

53. Ibid. p. 411

54. EXPLOSIVES AND OTHER DANGEROUS ARTICLES ON BOARD VESSELS. Washington, D. C., U. S. Coast Guard, July 1, 1954, p.216

55. Ibid. p. 292

56. Factory Mutual System, Factory Mutual Engineering Corp., Norwood, Mass.
HANDBOOK OF INDUSTRIAL LOSS PREVENTION. New York, McGraw-Hill Book Co., 1967, p.56-4

57. Ibid. p. 62-4

58. Fairhall, L. T.
INDUSTRIAL TOXICOLOGY. Baltimore, Md., Williams and Wilkins Co., 1957.

59. Feher, F., G. Jansen and H. Rohmer
THE CHEMISTRY OF SILICON AND GERMANIUM VI, THE HEATS OF FORMATION OF MONO-, DI-, TRI-, AND N-TETRASILANE. Zeitschrift fur Anorganische und Allgemeine Chemie (Leipzig), 329(1-2): 311-343, 1964.

60. Feher, F., G. Jansen, and H. Rohmer
HEATS OF COMBUSTION AND ENTHALPY OF FORMATION OF SiH_4, Si_2H_6, Si_3H_8, AND n-Si_4H_{10}. Angewandte Chemie (Weinheim) 75(18): 859, 1963.

61. Feltman Research and Engineering Lab., Picatinny Arsenal, Dover, N. J.
EXPLOSIVES RESEARCH SECTION SAFETY HANDBOOK. Dec. 1959, p.34. AD 233149

62. Feltman Research Labs., Picatinny Arsenal,
[FUNDAMENTALS OF PYROTECHNICS] Osnovy Pirotekhniki, by A. A. Shidlovsky. 1964. PA TM-1615, May 1965, p.289. AD 462474

63. Ibid. p. 308-309

64. Feytag, H. H.
[FIRE AND EXPLOSION] Feur und Explosionen (Koln) Aulis Verlag Deubner and Co., 1966. p.172

65. Fletcher, E. A., R. G. Dorsch and H. Allen, Jr.
COMBUSTION OF HIGHLY REACTIVE FUELS IN SUPERSONIC AIRSTREAMS. ARS jour., 30(4): 338, 1960.

66. Foreign Tech. Div., Air Force System Command, Wright Patterson Air Force Base, Ohio.
DETERMINING THE HEAT OF FORMATION OF DECABORANE, by G. U. Gal'chenko, B. I. Temsfeyev and S. N. Skuratov. Doklady Akademii Nauk SSSR, 42(5): 1077-1080, 1962. FTD-TT-62-985, July 9, 1962, 9p. AD 284153

67. Foreign Tech. Div., Air Force System Command, Wright Patterson Air Force Base, Ohio.
LIQUID ROCKET PROPELLANTS (Zhidkiye raketnyye topliva), by A. V. Sevegin. Moskva, Voyenniye Izdatel'stvo Ministerstva Oborony SSSR, 1962. FTD-TT-6398, Apr. 1963, 103p. AD 405726

68. Gaylord, N. G.
REDUCTION WITH COMPLEX METAL HYDRIDES. New York, Interscience Publishers, Inc., 1956. p.8.

69. Ibid. p. 22

70. Ibid. p. 25

71. Ibid. p. 58

72. Ibid. p. 73

73. General Applied Science Labs., Inc., Westbury, Long Island, New York.
HEAT TRANSFER DUE TO COMBUSTION ON A FLAT PLATE IN SUPERSONIC FLOW, by W. Chinitz and L. Spodaccini. GASL Tech. rept. 486. Dec. 1964, summary. AD 610613

74. Gilbert, L. L. and C. W. Funk
EXPLOSIONS OF TITANIUM AND FUMING NITRIC ACID MIXTURES. Metal Progress, 70(11): 93, 1956.

75. Gilkison, J. G.
COMMON ROCKET PROPELLANTS AND IGNITERS, PART III. Fire Eng., 116(11): 958, 1963.

76. Glistenko, N. I.
PREPARATION OF PYROPHORIC METALS. Trudy Voronezhskogo Gosudarstvennogo Universitetov, 42(2): 31, 1956. (CA 53: 8093g)

77. Gorrie, T. M., P. W. Kopf and S. Toby.
THE KINETICS OF THE REACTION OF SOME PYROPHORIC METALS WITH OXYGEN. Jour. Phys. Chem., 71(11): 3842-3845, 1967.

78. Gunn, S. R. and L. R. Green
THE HEATS OF FORMATION OF SOME UNSTABLE GASEOUS HYDRIDES. Jour. Phys. Chem., 65(5): 780-781, 1961.

79. HANDBOOK OF CHEMISTRY AND PHYSICS. Ed. by R. C. Weast and S. M. Shelby. Cleveland, Ohio, The Chemical Rubber Co., 1968.

80. HANDBOOK OF PREPARATIVE INORGANIC CHEMISTRY. Ed. by G. Brauer. New York, Academic Press, 1965.

81. HANDBOOK OF LABORATORY SAFETY. Ed. by N. V. Steere. Cleveland, Ohio, The Chemical Rubber Co., 1967.

82. Harwood, J. H.
INDUSTRIAL APPLICATIONS OF THE METAL ORGANIC COMPOUNDS. Chemistry and Industry (London), 12(11): 432, 1963.

83. Hedburg, K. and V. Schomaker
A REINVESTIGATION OF THE STRUCTURES OF DIBORANE AND ETHANE BY ELECTRON DIFRACTION. Jour. Amer. Chem. Soc., 73: 1482, 1951.

84. Hultgren, R. R., R. L. Orr and others.
SELECTED VALUES OF THERMODYNAMIC PROPERTIES OF METALS AND ALLOYS. New York, John Wiley and Sons, Inc., 1963, p. 641.

85. Ibid. p. 771

86. Ibid. p. 829

87. Ibid. p. 836

88. Ibid. p. 868, 871

89. Hurd, D. T.
AN INTRODUCTION TO THE CHEMISTRY OF THE HYDRIDES. New York, John Wiley and Sons, Inc., 1952, p. 36, 37.

90. Ibid. p. 38

91. Ibid. p. 48

92. Ibid. p. 98

93. Ibid. p. 99

94. Ibid. p. 111

95. Ibid. p. 128

96. Ibid. p. 163

97. HYGENIC GUIDE SERIES. Amer. Indus. Hyg. Assoc. Jour., 25(3): 314, 1964.

98. Illinois Inst. of Tech., Chicago.
INCENDIARY CAPSULE FIRING FLAME THROWER FEASIBILITY STUDY, PHASE III, EXPERIMENTAL EVALUATION OF CANDIDATE OPERATING PRINCIPLES, by M. S. Nusbaum. Summary rept. Nov. 17, 1960, p. 7. AD 247639

99. Illinois Inst. of Tech., Armour Research Foundation, Chicago.
INHIBITION OF FLASHING OF AEROSOLS, by R. Kamo. Quarterly progress rept. 7, Feb. 21, 1962, p.23. AD 272972.

100. Johns Hopkins Univ., Applied Physics Lab., Silver Spring, Md.
THE COMBUSTION OF BORON HYDRIDES, by W. G. Berl and W. Kenich. Rept. CM-542, July 1958, AD 207027

101. Johnson, W. H., R. A. Nelson and E. J. Prosen
HEATS OF FORMATION OF TITANIUM TETRACHLORIDE. Jour. Research of the National Bureau of Standards, 62(1): 49, 1959.

102. Karabash, A. G.
SEVERAL CHEMICAL PROPERTIES OF THORIUM AND URANIUM. Zhurnal Neorganicheskoi Khimii (Moskva), 3: 986-995, 1958. (CA 52: 18047d)

103. Kaufman, H. C.
HANDBOOK OF ORGANOMETALLIC COMPOUNDS. New York, D Van Nostrand Co., Inc., 1961.

104. Kit, B. and D. S. Evered
ROCKET PROPELLANT HANDBOOK. New York, The MacMillan Co., 1960. p.65.

105. Ibid. p. 68

106. Ibid. p. 75

107. Ibid. p. 76

108. Ibid. p.140

109. Ibid. p. 254

110. Ibid. p. 255

111. Knap, J. E., R. E. Leech and others.
SAFE HANDLING OF ALKYL ALUMINUM COMPOUNDS. Indus. and Eng. Chem., 49(5): 874-879, 1957.

112. Krucoff, D.
ARMOUR DUST-FUELED REACTOR. Nucleonics, 17(6): 100-106, 1959.

113. Kuhn, R. and W. Olting.
ACCIDENTS WHILE USING PYRIDINIUM PERCHLORATE; Chemiker-Zeitung (Heidelberg) 74: 139-140, 1950.

114. Lautsch, W. F., A. Tröker and others.
[METALORGANIC COMPOUNDS ENERGY DATA, PART I, COMBUSTION AND ENTHALPY OF FORMATION] Energetische Daten Metallorganischer Verbindungen. I Teil, Verbrennungs und Bildungsenthalpien. Zeitschrift für Chemie (Leipzig), 3: 416-418, 1963.

115. LEAD OXIDATION WORK MAY LEAD TO STANDARDS. Chem. and Eng. News, 44: 51, May 1966.

116. Lihl, F.
PYROPHORIC IRON OXIDE. Monatshefte für Chemie und Verwandte Teils anderer Wissenschaften (Wien), 81: 632-646, 1950. (CA 45: 3276i)

117. Lockheed Aircraft Corp., Sunnyvale, Calif.
ALUMINUM HYDRIDE, A LITERATURE REVIEW. Tech. note, Aug. 1960, p. 3. AD 244583

118. Ibid. p. 8

119. Ivid. p. 9

120. Long, L. H. and J. F. Sachman
HEAT OF FORMATION AND PHYSICAL PROPERTIES OF GALLIUM TRIMETHYL [TRIMETHYL GALLINE]. Trans. Faraday Soc., 54: 1797-1803, 1958.

121. Lyon, R. N.
LIQUID METALS HANDBOOK. NAVEXOS P-733. Washington, D. C., U. S. Government Printing Office, 1952, p. 40-41.

122. Ibid. p. 42-43

123. Manufacturing Chemists Assoc., Washington, D. C.
CASE HISTORIES OF ACCIDENTS IN THE CHEMICAL INDUSTRY V. 1, Washington, D. C., The Association, 1962, p. 145.

124. Manufacturing Chemists Assoc., Washington, D. C.
GUIDE TO PRECAUTIONARY LABELING OF HAZARDOUS CHEMICALS. Washington, D. C., The Association, 1961, p. 90.

125. MATERIAL FACTORS. Chem. Eng. Prog., 62(9): 128, 1966.

126. MATERIAL FACTORS. Chem. Eng. Prog., 62(12): 116, 1966.

127. MATERIAL FACTORS. Chem. Eng. Prog., 63(1): 127, 1967.

128. MATERIAL FACTORS. Chem. Eng. Prog., 63(2): 90, 1967.

129. MATERIAL FACTORS. Chem. Eng. Prog., 63(6): 118, 1967.

130. MATERIAL FACTORS. Chem. Eng. Prog., 63(7): 126, 1967.

131. Mellor, J. W.
A COMPREHENSIVE TREATISE ON INORGANIC AND THEORETICAL CHEMISTRY. New York, Longmans, Green and Co., 1936.

132. MERCK INDEX OF CHEMICALS AND DRUGS. Ed. by P. G. Stecher, M. J. Finkel and others. Rahway, N. J., Merck and Co., 1960.

133. METAL HYDRIDES. National Safety News, 77(2): 37-40, 1958.

134. Metal Hydrides Inc., Beverly, Mass.
ATTEMPTED SYNTHESIS OF BERYLLIUM HYDRIDE, by J. C. Powers, D. W. Vass and E. A. Sullivan. Rept for June 1958-July 1958 on Materials Analysis and Evaluation Techniques, WADD TC 60-543, Oct. 1960, p. 1. AD 249398.

135. METAL ORGANIC COMPOUNDS. Advances in Chemistry Series no. 23. Washington, D. C., American Chemical Society, 1957, p. 52.

136. Ibid. p. 176

137. METALS' DANGERS LISTED. Chem. and Eng. News, 36(8): 64, 1958.

138. Mirviss, S. B.
PYROPHORIC ORGANOMETALLICS. Indus. and Eng. Chem., 53(1): suppl. 58A-60A, 1961.

139. MSA Research Corp., Callery, Pa.
EXTINGUISHMENT OF ALKALI METAL FIRES, by S. J. Rodgers and W. A. Everson. Quarterly progress rept. 1, March 15-June 15, 1962. MSAR 62-65, June 18, 1962. p. 9. AD 291580

140. National Aeronautics and Space Administration, Washington, D. C.
HANDLING HAZARDOUS MATERIALS, by D. R. Cloyd and W. J. Murphy. Washington, D. C., U. S. Government Printing Office, 1965, p. 29-30. (SP-5032)

141. National Bureau of Standards, Washington, D. C.
PREPARATION OF PURE TITANIUM TETRACHLORIDE, by W. S. Clabaugh and R. Gilchrist. NBS rept. no. 3874, Jan. 15, 1955, p. 1-4. AD 56890

142. National Fire Protection Assoc., Boston, Mass.
HAZARDOUS CHEMICALS DATA. In: Fire Protection Guide on Hazardous Materials, 1966.

143. National Fire Protection Assoc., Boston, Mass.
MANUAL OF HAZARDOUS CHEMICAL REACTIONS. In: Fire Protection Guide on Hazardous Materials. 1966.

144. National Fire Protection Assoc., Boston, Mass.
NATIONAL FIRE CODES. VOLUME 3. COMBUSTIBLE SOLIDS, DUSTS AND EXPLOSIVES. 1965-1966. Boston, Mass. The Association, 1966.

145. National Fire Protection Assoc., Boston, Mass.
PROPERTIES OF FLAMMABLE LIQUIDS, GASES AND SOLIDS. In: Fire Protection Guide on Hazardous Materials. 1966.

146. New York Univ., New York.
THE THERMAL DECOMPOSITION OF ALUMINUM TRIETHYL, by Y. A. Tajima, G. Salser, and C. J. Marsel. Feb. 1961, Abstract. AD 257019

147. Noll, P. W.
HANDLING OF BORON PROPELLANTS FOR LIQUID ROCKET ENGINES. In: Proc. Propellant Thermodynamics and Handling Conf. (Ohio State Univ., Columbus, July 20-21, 1959). Ed. by L. E. Ballinger and A. W. Lemmon, Jr. Columbus, Ohio, Engineering Experiment Station, p. 90, 1960.

148. NRC TECHNIQUE GIVES ULTRAFINE METAL POWDERS. Chem. and Eng. News, 40: 57, Dec. 3, 1962.

149. Office of the Director of Defense Research and Engineering, Washington, D. C.
THE HANDLING AND STORAGE OF LIQUID PROPELLANTS. Jan. 1963, p. 27. AD 442849

150. Ibid. p. 71

151. Ibid. p. 177, 178

152. Ibid. p. 247

153. Ibid. p. 299-300

154. Olin Mathieson Chemical Corp., Niagra Falls, N. Y.
KINETICS OF THE PYROLYSIS OF DIBORANE, by J. H. Norman. OMCC-HEF-231, July 15, 1960. 12p. AD 246438

155. Pennsylvania State College, State College
THERMODYNAMIC PROPERTIES OF BORON AND ALUMINUM COMPOUNDS, by T. Wartik, M. J. Linevsky and H. Bowkley. Progress rept. 2, Jan. 1, 1953-Sept. 30, 1953. AD 19456

156. Pennsylvania Univ., Dept. of Chemistry, Philadelphia.
THE ALK/ALI METAL PHOSPHIDES AND THE LOWER HYDRIDES OF PHOSPHORUS, by E. C. Evers, E. H. Street, Jr. and others. Final rept. March 3, 1955, p. 11. AD 56692

157. Pennsylvania Univ., Philadelphia
CHEMISTRY OF THE LIGHTER ELEMENTS. Final rept. Dec. 30, 1960. AD 252094

158. Pennsylvania Univ., Philadelphia.
INFRARED REFLECTION STUDIES OF SINGLE CRYSTAL LITHIUM HYDRIDE AND ON ITS ISOTOPIC DERIVATIVE, by M. H. Brodsky and E. Burstein. Tech. rept. 4, Nov. 1965. p. 7. AD 476556

159. Ibid. p. 8

160. Ibid. p. 9

161. Papakin, V. I., T. N. Dymova and others.
HEAT OF FORMATION OF MAGNESIUM HYDRIDE. Zhurnal Fizicheskoi Khimii (Moskva), 38(4): 1024-1026, 1964. (CA 61: 1322f)

162. Picatinny Arsenal, Dover, N. J.
ENCYCLOPEDIA OF EXPLOSIVES AND RELATED ITEMS. V. 1. A TO AZOXY, by B. T. Federoff, O. E. Sheffield and others. Morristown, N. J., Compton Press, 1960: p. A169. (PATR-2700)

163. Picatinny Arsenal, Dover, N. J.
ENCYCLOPEDIA OR EXPLOSIVES AND RELATED ITEMS, V. 3. CHLORIDES TO DETONATING RELAYS, by B. T. Federoff and O. E. Sheffield. Dover, N. J., Picatinny Arsenal, 1966: D9-D11. (PATR-2700)

164. Picatinny Arsenal, Dover, N. J.
EXPLOSIVES RESEARCH SECTION SAFETY HANDBOOK. Dover, N. J., Picatinny Arsenal, Dec. 1959, p.28. AD 233149

165. Ibid. p. 34

166. Ibid. p. 40

167. Picatinny Arsenal, Dover, N. J.
THE PRODUCTION OF COLORED SMOKES FROM HIGHLY REACTIVE HYDROLYZABLE METAL CHLORIDES. (Technical memo. 1644) Table 4.

168. Pitzer, K. S. and H. S. Gutolosky
ELECTRON-DEFICIENT MOLECULES II ALUMINUM ALKYLS. Jour. Amer. Chem. Soc., 68: 2204, 1946.

169. Powlek, F.
MAGNETIC PROPERTIES OF AMALGAMS OF IRON METALS (IRON, NICKEL, COBALT, AND MANGANESE). Zeitschrift für Metallkunde (Stuttgart S.) 41: 452, 1950.

170. Prentiss, A. M.
CHEMICALS IN WAR: A TREATISE ON CHEMICAL WARFARE. New York, McGraw-Hill Book Co., Inc., 1937. p.237.

171. Ibid. p. 238

172. Ibid. p. 239

173. Princeton Univ., N. J.
PROJECT SQUID, by R. N. Pease. Quarterly rept. March 31, 1950, p. 1. TIP U12580.

174. PROGRESS IN BORON CHEMISTRY. VOL. 1. Ed. by H. Steinberg and A. L. McCloskey. New York, Pergamon Press, 1964.

175. Pruett, R. L. and J. E. Wyman
DIVANADIUM DODECACARBONYL. Chemistry and Industry (London),9(1): 119-120, 1960.

176. Raiziss, G. W. and J. L. Gavron
ORGANIC ARSENICAL COMPOUNDS. (ACS Monograph Series). New York, The Chemical Catalog Co., Inc., 1923.

177. Rand Corporation, Santa Monica, Calif.
PHYSICAL PROPERTIES AND THERMODYNAMIC FUNCTIONS OF FUELS, OXIDIZERS, AND PRODUCTS OF COMBUSTION. I. FUELS. Project Rand rept. R-127, NCL rept. S-23652, Jan. 1949, p. 27.

178. Ibid. p. 45-56

179. Ibid. p. 79

180. Ibid. p. 159

181. Ibid. p. 160

182. Ibid. p. 216-224

183. Raub, E., and M. Engels
SELF-IGNITING ALLOYS. Metallforschung (Stuttgart), 2: 115-119, 1947.

184. Rochow, E. G., D. T. Hurd and R. N. Lewis
THE CHEMISTRY OF ORGANOMETALLIC COMPOUNDS. New York, John Wiley and Sons, Inc., 1957.

185. Rocketdyne, (North American Aviation, Inc.), Canoga Park, Calif.
CHLORINE TRIFLUORIDE HANDLING MANUAL, by E. Suarez-Alfonso, A. E. Chambers and D. J. Hatz. AF/SSD-TR-61-9. Sept. 1961, p. 30. AD 266121

186. Rocketdyne, (North American Aviation, Inc.), Canoga Park, Calif.
HYPERGOL CARTRIDGE MAINTENANCE AND STORAGE. R-3066, July 13, 1961, p. 3. AD 445908

187. Ibid. p. 11

188. Rocketdyne, (North American Aviation, Inc.), Canoga Park, Calif.
RESEARCH ON THE HAZARD CLASSIFICATION OF NEW LIQUID ROCKET PROPELLANTS. Quarterly progress rept. for period ending Apr. 30, 1960. R-2452-1, p. 29-30. AD 245833

189. Rocketdyne, (North American Aviation, Inc.), Canoga Park, Calif.
RESEARCH ON THE HAZARD CLASSIFICATION OF NEW LIQUID ROCKET PROPELLANTS. Final rept. v. 1, Oct. 1961, p. 4. AD 272025

190. Rose, A., E. Rose and F. M. Turner
THE CONDENSED CHEMICAL DICTIONARY. New York, Reinhold Publishing Corp., 1961.

191. Rompp, H.
CHEMIE LEXIKON. V. 1. Stuttgart, Franckh's Verlagshandlung, 1962, p. 499.

192. Rosenberg, N. W.
CHEMILUMINESCENCE OF TRIMETHYL ALUMINUM RELEASED INTO THE UPPER ATMOSPHERE. Jour. Geophys. Research, 68(20): 5895-5898, 1963.

193. Rough, F. A. and R. F. Dickerson
URANIUM MONOCARBIDE - FUEL OF THE FUTURE? Nucleonics, 18(3): 74-77, 1960.

194. Susvári, K.
CONDITIONS OF FORMATION AND STRUCTURE OF β-TUNGSTEN. Wissenschaftlichte Zeitschrift der Hochschule fur Schwermaschinenbau Magdeburg (Magdeburg). 3: 175-181, 1960. (CA 54: 20752g)

195. Sax, N. I.
DANGEROUS PROPERTIES OF INDUSTRIAL MATERIALS. New York, Reinhold Publishing Corp., 1963.

196. Schlesinger, H. I., H. C. Brown and E. K. Hyde
THE PREPARATION OF OTHER BOROHYDRIDES BY METATHETICAL REACTIONS UTILIZING THE ALKALI METAL BOROHYDRIDES. Jour. Amer. Chem. Soc., 75: 210-211, 1953.

197. Schlesinger, H. I., H. C. Brown and others.
URANIUM (IV) BOROHYDRIDE. Jour. Amer. Chem. Soc., 75: 219-223, 1953.

198. Scholtz, W. F.
NAK, HOW TO HANDLE SAFELY. Safety Maintenance, 125(3): 18-21, 1963.

199. Shell Development Co., Emeryville, Calif.
THE INFLAMMABLE PROPERTIES OF COMBUSTIBLE MATERIALS, PART I, by A. S. Lehman and W. B. Wilson. Final rept. June 30, 1949, p. 46. AD 455079

200. Ibid. p. 50

201. Ibid. p. 52

202. Ibid. p. 53

203. Shell Development Co., Emeryville, Calif.
POTENTIAL CW AGENTS, TASK 5, BORON COMPOUNDS AS TOXICANTS, by V. W. Buls. Bi-monthly rept. 5, Apr.-May 1953, p. 2. AD 46023

204. Ibid. p. 3

205. Shell Development Co., Emeryville, Calif.
POTENTIAL CW AGENTS, TASK 5, BORON COMPOUNDS AS TOXICANTS, by V. W. Buls. Bi-monthly rept. 6, June-July 1953, p. 3. AD 46101

206. Ibid. p. 5

207. Ibid. p. 8

208. Ibid. p. 9

209. Ibid. p. 10

210. Shell Development Co., Emeryville, Calif.
POTENTIAL CW AGENTS, TASK 5, BORON COMPOUNDS AS TOXICANTS, by V. W. Euls. Bi-monthly rept. 8. Oct.-Nov. 1953, p. 4. AD 38431

211. Shelomentsev, I. I.
HAZARDS OF PYROPHORIC PROPERTIES OF PRODUCTS OF HYDROGEN SULFIDE CORROSION. Neftyanoye Khozyaistvo (Moskva), 25(7): 5153, 1947. (CA 42: 3303i)

212. Silverstein, M. S., G. F. Nordblom and others.
STABLE RED PHOSPHORUS. Ind. and Eng. Chem., 40: 301-303, 1948.

213. Smith, R. B.
PYROPHORICITY-TECHNICAL MYSTERY UNDER VIGOROUS ATTACK. Nucleonics, 14(12): 28, 1956.

214. Snell, F. D. and C. T. Snell
DICTIONARY OF COMMERCIAL CHEMICALS. New York, D. Van Nostrand Co., Inc., 1962.

215. Southern California Univ., Dept. of Chemistry, Los Angeles
STUDIES OF THE RARE EARTH HALIDES, by J. C. Warf and W. L. Korst. Tech. rept. 2, Oct. 1, 1952-Nov. 15, 1953. Nov. 15, 1953, p. 11. AD 23188

216. Southwest Research Inst., San Antonio, Tex.
PROPERTIES OF INORGANIC ENERGY CONVERSION AND HEAT TRANSFER FLUIDS FOR SPACE APPLICATIONS, by W. D. Weatherford, Jr., J. C. Tyler and P. M. Ku. WADD tech. rept. 61-96. Nov. 1961, p. Rb. gen. and syn. prop. Rb. AD 267541

217. Speele, A. B. and J. J. Duggan
SAFE HANDLING OF "REACTIVE" CHEMICALS. Chem. Eng., 66: 160, Apr. 20, 1959.

218. Stecker, H. E.
FIRE PREVENTION AND PROTECTION FUNDAMENTALS (COMBUSTIBLES). Philadelphia, Pa., Spectator, 1953. p. 302.

219. Steinberg, H. and R. J. Brotherton
ORGANOBORON CHEMISTRY. V. 2 BORON-NITROGEN AND BORON-PHOSPHORUS COMPOUNDS. New York, John Wiley and Sons, 1960. p. 166.

220. Stosick, A. J.
SPACE GROUP AND UNIT CELL OF BERYLLIUM BOROHYDRIDE. Acta Crystallographica (Copenhagen), 5(1): 151, 1952.

221. Temple Univ., Research Inst., Philadelphia, Pa.
EXPLORATORY RESEARCH ON HIGH ENERGY PROPELLANT SYSTEMS, by A. V. Grosse, T. F. Flint and others. Final rept. Jan. 1961. Table 3. AD 270941

222. Thomi, P.
TUNGSTEN POWDER. French patent no. 1,146,021. Nov. 5, 1957. (CA 53: 21572b)

223. U. S. Atomic Energy Commission, Washington, D. C.
BARIUM; A BIBLIOGRAPHY OF UNCLASSIFIED LITERATURE, by S. B. Schwind. Rept. TID-560, June 9, 1952. AD 5542

224. U. S. Atomic Energy Commission, Health and Safety Lab., Washington, D. C.
SAFE HANDLING OF PYROPHORIC AND RADIOACTIVE METAL POWDER, by W. B. Harris. In: Powder Metallurgy in Nuclear Engineering (Proc. Conf. Powder Metallurgy in Atomic Energy, Oct. 20, 1955, Philadelphia, Pa.) Cleveland, Ohio, American Society for Metals, p. 250, 1958.

225. U. S. Dept. of the Interior, Bureau of Mines, Washington, D. C.
REVIEW OF FIRE AND EXPLOSION HAZARDS OF FLIGHT VEHICLES COMBUSTIBLES, by R. W. Van Dolah, M. G. Zabetakis and others. ASD Tech. rept. 61-278, Apr. 1961, p. 37-38. AD 262989

226. U. S. Naval Ammunition Depot, Crane, Ind.
AIR REACTIVE COMPOUNDS: LISTING AND PROPERTIES, by B. E. Douda. RDTR no. 71. Feb. 24, 1966, AD 632686

227. U. S. Naval Ammunition Depot, Crane, Ind.
A BACKGROUND SURVEY OF AIR AND WATER REACTIVE MATERIALS AND THEIR USES, by W. Ripley. RDTN no. 32, Oct. 28, 1966.

228. U. S. Naval Ammunition Depot, Crane, Ind.
SAFETY MANUAL, THE LABORATORY PREPARATION OF PYROTECHNICS, by C. Armour. RDTR no. 29, July 27, 1962, p. 1

229. Ibid. p. 4

230. Urry, G., T. Wartick and others.
THE PREPARATION AND SOME OF THE PROPERTIES OF DIBORON TETRACHLORIDE, B_2Cl_4. Jour. Amer. Chem. Soc., 76(21): 5293, 5295, 1954.

231. Van Wazer, J. R.
PHOSPHORUS AND ITS COMPOUNDS. V. 1. New York, Interscience Publishers, Inc., 1958.

232. Von Schwartz, E.
[HANDBOOK OF FIRE AND EXPLOSION DANGER]. Handbuch der Feur und Explosionsgefahr. Munchen, Feurschutzverlag, 1964. p. 150

233. Ibid. p. 154

234. Ibid. p. 156

235. Vogel, R. von and H. Klose
[COMPOSITION AND PROPERTIES OF THE COBALT, NICKEL, MANGANESE ALLOY] Aufbau und Eigenschaften der Kobalt-Nickel-Mangan Legierungen. Zeitschrift fur Metallkunde (Stuttgart). 45: 638, 1954.

236. Whately, A. T. and R. N. Pease
OBSERVATIONS ON THERMAL EXPLOSION OF DIBORANE-OXYGEN MIXTURES. Jour. Amer. Chem. Soc., 76: 1997-1999, Apr. 1954.

237. Whately, A. T. and R. N. Pease
A KINETIC STUDY OF THE DIBORANE-ETHYLENE REACTION. Jour. Amer. Chem. Soc., 76: 835, Feb. 1954.

238. Woodward, L. A.
MOLYBDENUM OXIDE CATALYSTS FOR THE REDUCTION OF PHENOL TO BENZENE. Trans. Faraday Soc., 44: 608-616, 1948.

239. Wucher, J.
[MAGNETIC PROPERTIES OF THE NICKEL-LANTHUM ALLOYS] Proprietes Magnetiques des Alliages Nickel-Lanthane. Journal de Physique et le Radium (Paris), 13: 278-282, 1952.

240. Zehr, J.
PYROPHORIC DUSTS IN TECHNOLOGY AND INDUSTRY. Staub (Dusseldorf), 22(11): 494-508, 1962.

241. Zeiss, H.
ORGANOMETALLIC CHEMISTRY. New York, Reinhold Publishing Corp., 1960. p. 92.

242. Ibid. p. 129

243. Ibid. p. 364

244. Ibid. p. 394

245. Ibid. p. 432

246. Zingaro, R. A. and R. E. McG'lothlin
PHYSICAL PROPERTIES EVALUATION OF COMPOUNDS AND MATERIALS. PART II. SOME PHOSPHINES, PHOSPHINE SULFIDES AND PHOSPHINE SELENIDES. Jour. Chem. and Eng. Data, 8(2): 227, 1963.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA R & D

Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
Special Bibliographies Section
Science and Technology Division
Library of Congress
Washington, D. C. 20450

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

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

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Report January 1966 - December 1968

5. AUTHOR(S) (First name, middle initial, last name)

Jack R. Gibson
Jeanne D. Weber

6. REPORT DATE
December 1968

7a. TOTAL NO. OF PAGES
216

7b. NO. OF REFS
246

8a. CONTRACT OR GRANT NO

b. PROJECT NO AIRTASK No. A35-532-022/323-1/F00-17-02 Work Unit No. 15

c.

d. N00164 - 67 - C - 0498

9a. ORIGINATOR'S REPORT NUMBER(S)

Final Report RDTR No. 144

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

NAD Crane RDTR #144

10. DISTRIBUTION STATEMENT

Distribution of this document is unlimited

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

U. S. Naval Ammunition Depot
Crane, Indiana 47522

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).

DD FORM 1473 (PAGE 1)

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Chemical Properties						
Data Sheets						
Hypergolic Substances						
Physical Properties						
Pyrophoric Substances						