

University of Pittsburgh Safety Manual	EHS Policy #	02-005
Subject: COMBUSTIBLE METALS	Effective Date	Page 1 of 7
	1/1/07	

COMBUSTIBLE METALS

These guidelines provide requirements for all University faculty, staff, and students using, handling, or storing combustible metals. These requirements are established to ensure faculty, staff and students know the physical characteristics of the material used and the protective measures necessary to prevent fire, explosion, or violent reaction.

1. Definitions

- 1.1 Alkali Metals: The alkali metals sodium, potassium, lithium, rubidium and cesium are the most reactive class of metals. They are highly combustible, react with water to generate hydrogen, and are easily ignited.
- 1.2 Combustible Metal: Any metal, composed of distinct particles or pieces, regardless of size, shape, or chemical composition, that will burn.
- 1.3 Combustible Metal Dust: Any finely divided metal 420 μm (microns) or smaller in diameter (that is, material passing a U.S. No. 40 standard sieve) that presents a fire or explosion hazard. Any time a combustible dust is processed or handled, a potential for explosion or fire exists. The degree of hazard will vary depending on the type of combustible dust, conditions, amount of material present, and processing methods used.
- 1.4 Chips: Particles produced from a cutting or machining that are not oxidized and that are not diluted by noncombustible materials. Chips vary in ease of ignition and rapidity of burning, depending on their size and geometry.
- 1.5 Ribbon: A piece of metal that is less than $\frac{1}{8}$ in. (3.2 mm) in two dimensions or less than $\frac{1}{16}$ in. (1.3 mm) in single dimension is considered a powder for the purposes of this standard.
- 1.6 Pyrophoric Material: A substance capable of self-ignition on short exposure to air under ordinary atmospheric conditions. Dispersions of alkali metals in organic solvents present special concerns. In addition to the water reactivity/pyrophoricity due to the reactive metal, the solvent presents the concerns of flammable or combustible liquids and vapors. In addition, the MSDS provided by the supplier of the material and "The Storage and Handling of Flammable and Combustible Liquids" Section of this manual, are applicable to address the hazards associated with combustible liquids and vapors.

2. General Hazards Description

Most metals are combustible to a varying degree, depending on the physical conditions. Many also undergo dangerous reactions with water, acids, and certain other chemicals. Some are

University of Pittsburgh Safety Manual	EHS Policy #	02-005
Subject: COMBUSTIBLE METALS	Effective Date	Page 2 of 7
	1/1/07	

subject to spontaneous heating and ignition. The hazard of an individual metal or alloy can vary widely depending on the particle size and shape that is present.

2.1 Alkali Metals:

- 2.1.1 **Sodium (Na):** Specific gravity, 0.97; melting point, 208°F (98°C). In University laboratories, sodium metal is most often used to remove excess water from flammable liquids during the distillation process. It is also used in the production of other sodium-based compounds and in the reduction of organic esters.

Sodium metal reacts violently with water to produce hydrogen gas and sodium hydroxide. The exothermic heat of this reaction can lead to auto-ignition of the hydrogen gas and/or the metal itself and create a severe fire or explosion hazard. Due to its low melting point, explosions of molten sodium may occur during reaction with water. Residual liquid present following the reaction contains a high percentage of sodium hydroxide, a caustic, corrosive material.

In finely divided form, sodium ignites spontaneously in air. Molten sodium reacts with most gases and liquids except the noble gases and nitrogen, and combines vigorously with hydrogen to form the hydride. Solid sodium reacts strongly with water, alcohol, polyhalogenated hydrocarbons, halogens, acidic oxides, sulfuric acid, mercury, and certain alloys of lead, tin, zinc and bismuth.

- 2.1.2 **Potassium (K):** Specific gravity, 0.86; melting point, 145°F (63°C). Similar to sodium in its pyrophoricity, chemical activity, and hazards although somewhat more reactive. It is violently reactive with sulfuric acid and most halogens. It will detonate in contact with liquid bromine.
- 2.1.3 **Lithium (Li):** Specific gravity, 0.53; melting point, 356°F (180°C). As the hydride, lithium offers the most concentrated method of storing and transporting hydrogen. Ignition and burning occur when lithium is heated to about 356°F (180°C). It reacts less vigorously than sodium with water or air, and usually does not ignite. It reacts strongly with chlorinated, fluorinated, and brominated organic compounds, halogens, and sulfuric acid. In the presence of moisture, lithium reacts exothermically with nitrogen at ordinary temperatures. Above the melting point, it rapidly forms the nitride. Near its melting point, it ignites in air and burns with a characteristic intense, brilliant white flame. Following treatment with nitric acid, it may explode on very light impact or friction. Lithium also reacts violently with hydrogen peroxide.

- 2.2 **Magnesium (Mg):** Specific gravity, 1.74; melting point of 1202°F (650°C). Its ignition temperature is near the melting point, although ignition of some

University of Pittsburgh Safety Manual	EHS Policy #	02-005
Subject: COMBUSTIBLE METALS	Effective Date	Page 3 of 7
	1/1/07	

forms may occur at lower temperatures. As a dust cloud or in ribbon form, magnesium can be ignited almost instantly. Loose shavings ignite fairly readily. It is less easy to ignite the surface of a compact pile of chips. Magnesium fines wet with oils may ignite spontaneously. Fines wet with acids, water, water-soluble oils, or oils containing fatty acids will generate hydrogen. Powders form explosive mixtures with air that may be ignited by a spark. Fines will also react with chlorine, bromine, iodine and oxidizing agents.

3. General Guidelines for Combustible Metals

- 3.1 The volume of combustible metals in a lab, room or location is restricted by University guidelines and International Fire Codes. EH&S should be contacted regarding any questions or for additional guidance.
- 3.2 The amount of combustible metal shall be kept to the minimum necessary for the work being done.
- 3.3 Combustible metals should be segregated and stored separately from incompatible materials such as water, acids, halogens, oils, and ordinary combustibles (paper, cardboard, etc).
- 3.4 Where possible, combustible metals should not be exposed to sources of heat, open flames or sparks.
- 3.5 The following safeguards should be applied to water reactive metals (sodium, potassium, magnesium):
 - 3.5.1 They should be stored in cabinets in order to minimize exposure to water spray, pooling or drainage from sources such as sprinklers, domestic water, or process water lines or systems.
 - 3.5.2 Ensure that the preparation area is completely dry of pooled water or any moisture.
 - 3.5.3 Any tools such as knives (when cutting metals such as sodium), tongs or other equipment used to handle or process the metals should also be kept free of water and moisture.
- 3.6 Excess metal chips, fines, ribbons or other leftover pieces from processes should be immediately collected and properly stored or disposed of in accordance with the University's chemical waste program to minimize additional hazards or possible exposures.

University of Pittsburgh Safety Manual	EHS Policy #	02-005
Subject: COMBUSTIBLE METALS	Effective Date	Page 4 of 7
	1/1/07	

- 3.7 In order to prevent alkali metals from reacting with water during storage, handling or other usage, the metal shall be immersed in kerosene or mineral oil within a noncombustible, sealed container.
- 3.8 When using metals such as sodium for solvent purification, the solvent stills should be:
- 3.8.1 Kept in the fume hood at all times.
- 3.8.2 Clearly labeled to identify the contents of each still.
- 3.9 Class D type fire extinguisher shall be provided by EH&S and funded by the user in areas storing, handling or using combustible metals. Materials such as dry sand, clay or other dry, inert materials should also be available to help smother a potential combustible metal fire. **DO NOT** use water, carbon dioxide, AFFF foam or multi-purpose (ABC) type fire extinguishers on combustible metal fires.

4. Other Highly Combustible Metals

Hafnium, plutonium, thorium, uranium and zirconium are all highly combustible metals. The hazards of this group are similar to those of magnesium, and the same safeguards should be applied except as noted in the following:

Uranium isotopes 233 and 235, plutonium, and thorium are radioactive, and present the same fire and explosion hazards as other combustible metals. They have been known to ignite spontaneously. As coarse particles, metals in this group offer little hazard; but in powder form, they present severe dust explosion possibilities. Some burn readily in pure nitrogen or carbon dioxide gas, and explode on contact with oxidizing agents. Some heat spontaneously in air and must be stored and handled under a nonreactive liquid or gas. Chips and other fine particles ignite easily, and special care is needed to prevent ignition of chips by the friction of cutting. Fine particles of these metals should be shipped and stored in approved DOT containers.

When molten or when burning, all these metals react vigorously with water, foam, carbon dioxide vaporizing liquid, and dry chemical extinguishing agents. Applied directly to the burning material, these agents will intensify burning and may cause an explosion. Approved dry powder extinguishing agents, dry sand, graphite chips, limestone, or talc are used to smother fires.

Hafnium (Hf): Specific gravity, 13.36; melting point, 4032°F (2222°C). Fines are pyrophoric. The metal burns with little visible flame but with a high rate of heat release. Reacts with water to form hydrogen, which may ignite spontaneously. Its hazards are similar to those of zirconium. Crushing and sizing should be carried out under inert gas.

Plutonium (Pu): Specific gravity, 19.6; melting point, 1170°F (632°C). It is pyrophoric, highly toxic (particularly in the oxide form when burning), and radioactive. Chips, turnings, and fine particles may ignite spontaneously. It is easily ignited by friction.

University of Pittsburgh Safety Manual	EHS Policy #	02-005
Subject: COMBUSTIBLE METALS	Effective Date	Page 5 of 7
	1/1/07	

Thorium (Th): Specific gravity, 11.6; density, melting point, 3090°F (1700°C). Thorium is pyrophoric and radioactive. As a dry powder it has a low ignition temperature. Thorium powder is shipped under helium or argon gases in special containers. When poured through air, it is subject to ignition by electrostatic spark. It should be handled cautiously with a nonsparking spoon or scoop. Containers and tools should be grounded. Ignition has occurred due to chemical reaction between finely divided thorium and water at ordinary temperatures.

Uranium (U): Specific gravity, 18.68; melting point, 2071°F (1132°C). The fire hazard of metallic uranium is similar to but more severe than magnesium. In finely divided form, it is pyrophoric. Spontaneous fires have occurred under argon, under vacuum, and under water. The high temperature reaction of uranium with steam is very violent. Radioactivity and products of combustion present a health hazard. Uranium powder should be handled in an inert atmosphere. Chips and turnings may be stored if completely immersed in water with ventilation to remove evolved hydrogen. Partial submersion or slight moistening accelerates spontaneous heating.

Zirconium (Zr): Specific gravity, 6.51; melting point 3326°F (1830°C). Fine particles in dust layers or clouds are pyrophoric, and may be ignited by heat, static or friction. Particles can be ignited in nitrogen gas above 986°F (530°C) and in carbon dioxide above 1040°F (560°C). Zirconium samples may explode during or following treatment with strong nitric acid or carbon tetrachloride. Samples have also exploded while being dissolved in a mixture of sulfuric acid and potassium acid sulfate. Particles form explosive mixtures with barium nitrate, potassium chlorate, and other oxidizing materials. In dry powder form, zirconium or zirconium-copper alloys in glass containers may explode by impact or friction if the container breaks. It ignites more easily than magnesium and is slightly less hazardous than uranium. Zirconium powder is commonly handled wet because it is then more difficult to ignite, although once ignited it will burn more violently. At least 25 percent moisture by weight should be present.

5.0 Miscellaneous Metals

Certain other metals in molten form or as fine particles present varying degrees of hazard. They may be subject to spontaneous heating, chemical activity, dust explosions, or ignition under favoring conditions.

Aluminum (Al): Aluminum is used both as a commercially pure metal and as an alloy. In finely divided powder or dust form, aluminum and its alloys are combustible in air and present a serious combustion explosion hazard. Aluminum will react violently with many chemicals. Aluminum particles and smaller turnings will react with water to form hydrogen gas which is highly flammable and explosive in favorable concentrations. The rapid vaporization of water in contact with molten aluminum can result in rapid phase transformation explosions. Halogenated extinguishing agents should not be used.

Antimony (Sb): Specific gravity, 6.62; melting point, 1166°F (630°C). It ignites and burns in air above 780°F (416°C).

Barium (Ba): Specific gravity, 3.5; melting point, 1300°F (704°C). In contact with water, it liberates hydrogen but usually without ignition.

University of Pittsburgh Safety Manual	EHS Policy #	02-005
Subject: COMBUSTIBLE METALS	Effective Date	Page 6 of 7
	1/1/07	

Beryllium (Be): Specific gravity, 1.85; melting point, 2400°F (1316°C). It is also called glucinum. It decreases the combustibility of molten aluminum and magnesium. As a powder, ignition may occur if the metal is heated to about 1115°F (600°C). Burning occurs with an intense flame, but can be extinguished by water. Beryllium powder should be kept away from air and moisture and stored in tight containers, preferably under argon gas. Beryllium and its compounds are very toxic and contact with skin or inhalation of dust or fumes should be avoided.

Bismuth (Bi): Specific gravity, 9.80; melting point, 520°F (271°C). It burns in air with bluish flame when vaporized and oxidizes rapidly when molten. At red heat, bismuth decomposes steam. It reduces carbon dioxide, but does not react with nitrogen or hydrogen.

Calcium (Ca): Specific gravity, 1.55; melting point, 1562°F (850°C). In contact with water, calcium liberates hydrogen but usually without ignition. It is considered pyrophoric under some conditions and is normally shipped in lump form under argon.

Cadmium (Cd): Specific gravity, 8.65; melting point, 610°F (321°C). It oxidizes when heated, giving off dense brown fumes that decompose steam above 750°F (400°C). As a powder it decomposes hot water but without igniting.

Chromium (Cr): Specific gravity, 7.19; melting point, 3407°F (1875°C). It presents a moderate dust explosion hazard under favorable conditions of partial size dispersion and ignition source.

Copper (Cu): Specific gravity, 8.96; melting point, 1981°F (1083°C). Copper is not known to produce explosive properties when in finely divided form.

Iron (Fe): Specific gravity, 7.86; melting point, 2802°F (1540°C). Iron presents a dust hazard under favoring conditions of particle size and dispersion in air. It can be easily ignited in the form of dust or steel wool or as fine turnings or chips containing oil. Structural steel has a specific gravity of 7.83 and melting point of 2605°F (1430°C). When heated above 600°F (315°C), it begins to lose strength rapidly.

Lead (Pb): Specific gravity, 11.34; melting point, 621°F (327°C). At high temperatures lead volatilizes and burns with white flame. At red heat, it is rapidly oxidized by air and at white heat by steam.

Manganese (Mn): Specific gravity, 7.43; melting point, 2246°F (1230°C). Its dust cloud can be ignited at 840°F (449°C) in air.

Molybdenum (Mo): Specific gravity, 10.2; melting point, 4750°F (2620°C). Molybdenum powder reacts vigorously with water vapor at 1300°F (704°C). It presents a slight dust hazard under favoring conditions of particle size, dispersion, and strong ignition source.

Silicon (Si): Specific gravity, 2.33; melting point, 2588°F (1420°C). A silicon dust cloud can be ignited in air at 1425°F (775°C). Pure silicon metal dust has been shown to be highly explosive under certain conditions.

University of Pittsburgh Safety Manual	EHS Policy #	02-005
Subject: COMBUSTIBLE METALS	Effective Date	Page 7 of 7
	1/1/07	

Strontium (Sr): Specific gravity, 2.6; melting point, 1386°F (752°C). In contact with water, it liberates hydrogen readily, but usually without ignition.

Tantalum (Ta): Specific gravity, 16.62; melting point 5425°F (2996°C). It presents a moderate dust explosion hazard under favorable conditions of particle size, dispersion, and ignition source.

Tellurium (Te): Specific gravity, 6.24; melting point, 846°F (452°C). It presents a moderate dust explosion hazard under favoring conditions of particle size, dispersion and ignition source.

Thallium (Tl): Specific gravity, 11.85; melting point, 572°F (300°C). At red heat it decomposes water, producing hydrogen. It is very toxic.

Tin (Sn): Specific gravity, 7.29; melting point, 450°F (232°C). Its dust cloud can be ignited in air at 1165°F (630°C).

Titanium (Ti): Specific gravity, 4.51; melting point, 3040°F (1670°C). At red heat, 1300°F (704°C), the metal actively decomposes steam. Following strong nitric acid treatment, the metal may explode by the light impact or friction of handling with tongs. The powder can be ignited in pure carbon dioxide above 1260°F (682°C), in nitrogen above 1475°F (801°C), and in air at 626°F (330°C) to 1094°F (590°C). Powdered titanium immersed in water or wet with water at ordinary temperatures has been ignited by chemical reaction.

Tungsten (W): Specific gravity, 19.2; melting point, 6115°F (3380°C). As fine powder, tungsten may be pyrophoric. Hydrogen reduced powder may retain some absorbed hydrogen, presenting a dust explosion hazard. Tungsten reacts violently with molten nitrates, nitrites, and peroxides.

Zinc (Zn): Specific gravity, 7.13; melting point 786°F (419°C). In the form of dust, in contact with moisture, alkaline solutions, or acetic acid, zinc will heat spontaneously to ignition. Large pieces of zinc are difficult to ignite but once ignited will burn strongly. In oxygen, oxidation of the metal takes place rapidly at 300°F (149°C) and ignition occurs at 930°F (499°C) with a bluish flame. Steam is decomposed on contact with zinc at 660°F (349°C). Acids or caustic soda also liberate hydrogen on contact with zinc. In air, zinc burns to the oxide, forming white or bluish smoke. As a dust cloud, it can be ignited at 1110°F (600°C).