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Hazard Data for Chemicals Used in Pyrotechnics

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In recent months, the authors have received a surprising number of requests for sources of chemical hazard information. Perhaps this is a consequence of the industry's increasing concern for health and safety. Whatever the reason for the requests for information, the authors have prepared this article to assist those needing to locate reliable and practical hazardous chemical information.

Perhaps the most commonly used reference text on chemical hazards is the *Hazardous Chemicals Desk Reference* ***(HCDR)*** by Sax and Lewis; published by Van Nostrand Reinhold. If this is the only reference consulted in evaluating potential chemical hazards, a very strong word of caution is warranted. The ***HCDR*** assigns a "Hazard Rating" to each of the approximately 5000 chemicals listed. However, these ratings are based exclusively on chemical toxicity. Often included in the discussion about each chemical is some information on reactivity and flammability. Unfortunately, that information is quite general in terms of hazard level (e.g., "moderate fire hazard" or "slight explosion hazard") and it is not considered at all in assigning the overall hazard rating to the chemical. Thus, the first word of caution is that users of the ***HCDR*** must not assume that its hazard ratings apply to anything more than chemical toxicity.

In the ***HCDR***, toxicities are addressed in terms of LD_{50}'s. (For a chemical, its LD_{50} is the weight of that chemical, in milligrams per kilogram of body weight, which will constitute a lethal dose to 50% of those persons exposed, within a specified period of time.) The hazard ratings are divided into three categories:

HR3, LD_{50} < 400 mg/kg;

HR2, LD_{50} > 400 mg/kg, but < 4,000 mg/kg; and

HR1, LD_{50} > 4,000 mg/kg, but < 40,000 mg/kg.

One might assume that there is a fourth (implicit) hazard-rating category, HR0, for chemicals with essentially no toxic hazard. Further, one might assume that this was the hazard rating assigned to all common chemicals not included among the 5000 listed. The latter assumption certainly is not true. Thus, the second word of caution is that it could be a serious mistake for a reader to assume that any chemical not listed in the ***HCDR*** is relatively non-toxic.

This article has addressed two areas in which the ***HCDR*** may understate the hazards associated with some chemicals. While these are of concern, it is not the area of greatest concern regarding the use of the ***HCDR***. As a result of stopping with HR3 as the greatest toxicity hazard, instead of having at least a HR4 and HR5, the ***HCDR*** equates chemicals of vastly differing toxic hazards, listing them all as HR3. The problem is that one is often left without the appropriate guidance as to how to handle many toxic chemicals. An illustration of this problem for chemicals with the highest reported toxic hazard (HR3), one might think it would be totally inappropriate to ever eat them, cook in them, breathe them, wear them as clothing and jewelry, or spread billions of pounds of them around in our cities. One might think that but it would not be true. Consider the following list of chemicals all rated as having the highest toxicity, HR3: Fruit Sugar (Fructose), Milk Sugar (Lactose), Vitamins (A, B_3, B_6, B_{12}, C), Grain Alcohol (Ethanol), Caffeine, Aluminum, Teflon, Oxygen, Silk, Nylon, Gold, Silver, Platinum, and (Road) Asphalt. The list of materials with HR3 is incredible, and also includes, Penicillin, Human Sperm, Cellophane, Rust (Iron Oxide), and Gasoline. Most, if not all, of these things are not what comes to mind when one thinks of "extremely toxic" chemicals for which special care is required. Your dilemma when using the ***HCDR***, and finding a chemical listed as HR3, is how should it be handled; take along a spoon (in case you get hungry and want a snack) or don disposable coveralls and a respirator. In large measure the problem would be eliminated if higher hazard ratings (HR4 and HR5) were used for those chemicals that deserve those higher ratings. The authors of the ***HCDR*** chose not to do this; thus the final word of caution is to definitely seek further chemical hazard information than can be found in the *Hazardous Chemicals Desk Reference*.

Another commonly used reference for hazard information, is the National Fire Protection Association's document, NFPA 49–1975 *Hazardous Chemicals Data (**HCD**)*. The authors suggest this is a better source of information, but that it still falls significantly short of meeting a person's need for hazardous chemical information. (This NFPA document will be replaced by a new version later this year, but it will contain the same basic deficiency discussed in this article.)

The major strength of the ***HCD*** listing is that it provides safety information in three areas: Health, Flammability, and Reactivity. The listed chemicals are assigned a rating from 0 to 4 in each category, with 0 corresponding to "no special hazard" and 4 corresponding to an "extreme hazard." Another strength of the ***HCD*** listing is that it provides other useful information such as a description of the material, extensive information on fire hazards including explosive hazards in fire situations, and proper storage practices.

Unfortunately, the ***HCD*** listing's of health hazard ratings are based only on acute health hazards. (Note that acute health hazards are those associated with exposures for limited time periods, e.g., hours, whereas chronic hazards are those associated with exposures over very much longer periods, e.g., years.) Fireworks plant personnel's exposure to hazardous chemicals will normally only be for extended time periods; thus it is both acute and chronic health hazards that are of interest. Another, and probably the most serious weakness of the ***HCD*** listing is that all its hazard ratings are in the strict context of fire fighting situations. Quite simply, this is a hazard rating system designed to be of use to fire service personnel when fighting chemical fires. Occasionally the ***HCD*** listing also includes hazard ratings for "non-fire" situations. However, even then, the ratings are in the context of the unique needs of fire service personnel. The ***HCD*** listing's hazard ratings are often applicable to the needs of others, but not always. As obvious examples of when the NFPA system breaks down for use by non-fire service personnel, consider the following ***HCD*** hazard ratings:

- Nitric and hydrochloric acids are rated as 0 Reactivity Hazard (i.e., non-reactive). This is because, in a fire situation, they are stable and unreactive with water (and other fire extinguishing agents). However, anyone that has physical contact with concentrated nitric or hydrochloric acid will be quick to attest that they are indeed dangerously reactive.
- Potassium chlorate and many of the most common pyrotechnic oxidizers are rated as 0 Reactivity Hazard, regardless of their potential to react explosively with powdered fuels.
- Lead nitrate and barium nitrate, in non-fire situations, are rated as 0 Health Hazard, regardless of the fact that they are water soluble, which makes them heavy metal poisons. (Note that the ***HCDR*** assigns these their highest toxic hazard rating, 3.)

The *Hazardous Chemicals Data* listing (NFPA 49) may be invaluable to fire service personnel. However, fireworks plant operators needing chemical hazard information should be very cautious in using these hazard ratings, even those listed as applicable to non-fire situations.

In terms of completeness, the best sources of chemical hazard information are Material Safety Data (MSD) sheets. These are the documents required by OSHA's Hazard Communication standard (29 CFR 1910.1200) for all hazardous materials and must be on the premises of any commercial site where those materials are being used or stored. MSD sheets generally are two to four pages in length and, when properly completed, contain a wealth of information. Among the facts documented on MSD sheets are: general chemical data, a list of hazardous ingredients, physical data, fire and explosion data, health hazard data, reactivity data, spill or leak procedures, special protection information, and special precautions.

As good as MSD sheets are, it must be acknowledged, that their exclusive use may also present some practical problems. In part this is because of all the highly technical information they contain; they are somewhat difficult for plant personnel to interpret and understand.

Considering the ease of use, the authors feel the J.T. Baker SAF–T–DATA system should be considered as a practical adjunct to the use of MSD sheets. The SAF–T–DATA system assigns a hazard rating from 0 (no known hazard) to 4 (extreme hazard) in each of four areas. The hazard areas are Health, Flammability, Reactivity, and Contact, where:

- Health hazard is the danger or toxic effect of a substance if inhaled, ingested, or absorbed;
- Flammable hazard is the tendency of the substance to burn in air;
- Reactivity hazard is the potential of a substance to explode or react violently with air, water, or other substances (e.g., substances with a flammability hazard); and
- Contact hazard is the danger a substance presents when exposed to skin, eyes, and mucous membranes.

A listing of SAF–T–DATA ratings is included in J.T. Baker's chemical catalog for those materials that they sell. However, as a convenience, the authors have prepared a listing of those chemicals one is likely to encounter in pyrotechnics and their hazard ratings.

SAFETY RATING SYSTEM FOR PYRO-CHEMICALS

0 = None,
1 = Slight,
2 = Moderate,
3 = Severe, and
4 = Extreme.

The safety ratings are given for four areas of hazard concern:

H = Health is danger or toxic effect a substance presents if inhaled, ingested, or absorbed,

F = Flammability is the tendency of the substance to burn,

R = Reactivity is the potential of a substance to explode or react violently with air, water or other substances, and

C = Contact is the danger a substance presents when exposed to skin, eyes, and mucous membranes.

Description	**H**	**F**	**R**	**C**
Accroides resin (red gum)	1	2	0	1
Acetone (nitrocellulose solvent)	1	3	2	1
Aluminum (400 mesh flake)	1	4	2	1
Aluminum (325 mesh, granular)	1	3	2	1
Ammonium dichromate	4	1	3	3
Ammonium nitrate	1	0	3	2
Ammonium perchlorate	1	0	3	2
Anthracene	1	1	0	1
Antimony trisulfide (325 mesh)	3	3	2	1
Barium carbonate	1	0	0	1
Barium chlorate	3	0	3	1
Barium nitrate	3	0	3	1
Barium sulfate	1	0	0	0
Benzene	4	3	2	1
Boric acid	2	0	0	2
Cab-o-sil (colloidal silica)	2	0	0	1
Calcium Carbonate	0	0	0	1
Calcium Sulfate	1	0	0	1
Charcoal (80 mesh)	0	1	0	1
Charcoal (air float)	0	2	0	1
Chlorowax	2	1	1	1
Clay (bentonite)	1	0	0	0
CMC (sodium carboxymethylcellulose)	1	1	1	1
Copper(II) carbonate (basic)	2	0	0	1
Copper(II) oxide (black)	2	0	0	1
Copper oxychloride	2	0	0	1
Copper(II) sulfate	2	0	0	2
Cryolite	1	0	0	1
Dechlorane	2	1	1	2
Dextrin (yellow)	0	1	0	0
Gallic acid, monohydrate	1	1	0	1
Graphite (325 mesh)	1	2	0	0
Hexachlorobenzene (HCB)	2	1	1	1
Hexachloroethane (HCE)	2	1	1	1
Hexamine (hexamethylenetetramine)	1	1	1	1
Hydrochloric acid (conc.)	3	0	2	3
Iodine, sublimed	3	0	2	3
Iron(II) oxide (black)	1	0	1	1
Iron(III) oxide (red)	1	0	1	1
Isopropanol (isopropyl alcohol)	1	3	1	1

Description	H	F	R	C
Lactose	0	1	1	0
Lampblack (oil free)	1	2	0	1
Lead, granular	3	0	0	1
Lead dioxide	3	0	3	1
Lead nitrate	3	0	3	1
Lead oxide (red, minium)	3	0	1	1
Magnesium (200 mesh)	1	3	2	0
Magnesium (325 mesh)	1	4	2	0
Magnesium alum. 50/50 (gran., 100–200 m.)	1	3	2	1
Magnesium alum. 50/50 (gran., 200–400 m.)	1	4	2	1
Magnesium carbonate	1	0	1	0
Manganese dioxide	1	0	1	1
Methanol (methyl alcohol)	3	3	1	1
Methylene chloride	3	1	1	2
Mineral oil	1	1	0	1
Nitric Acid (Concentrated)	3	0	3	4
Nitrocellulose (lacquer 10% solution)	1	3	2	1
Paraffin oil	1	1	0	1
Parlon (chlorinated natural rubber)	2	1	1	1
Phosphorous, red	0	2	2	2
Picric acid, crystal	2	2	2	2
Polyvinyl chloride (PVC)	2	1	1	1
Potassium, lump	3	3	3	4
Potassium bicarbonate	1	0	1	0
Potassium chlorate	1	0	3	2
Potassium dichromate (fine granular)	4	0	3	3
Potassium hydroxide, pellets	3	0	2	4
Potassium nitrate	1	0	3	2
Potassium perchlorate	1	0	3	2
Potassium permanganate	2	0	3	2
Potassium sulfate	1	0	0	0
PVC (polyvinyl chloride)	2	1	1	1
Red gum (accroides resin)	1	2	0	1
Shellac (–120 mesh, orange)	1	2	0	1
Silica (fumed-colloidal, Cab-o-sil)	2	0	0	1
Silica gel (60–200 mesh)	2	0	0	1
Silicon metal powder (325 mesh)	2	3	1	1
Silver nitrate, crystal	3	0	3	3
Smoke dye	1	1	1	2
Sodium, lump	3	3	3	4

Description	H	F	R	C
Sodium azide	3	2	3	2
Sodium benzoate	1	1	0	1
Sodium bicarbonate	0	0	1	1
Sodium carboxymethyl-cellulose (CMC)	1	1	1	1
Sodium chlorate, crystal	1	0	3	1
Sodium cyanide, granular	3	0	2	3
Sodium hydroxide, pellets	3	0	2	4
Sodium nitrate	1	0	3	1
Sodium oxalate	3	0	1	2
Sodium salicylate	1	1	0	1
Sodium silicate (water glass, liquid)	1	0	0	2
Sodium sulfate	0	0	0	1
Starch, soluble potato	0	1	0	1
Stearic acid	1	1	1	1
Strontium carbonate	1	0	0	1
Strontium nitrate	1	0	3	1
Strontium sulfate	1	0	0	1
Sulfur (flour)	1	1	0	1
Sulfuric acid (Conc.)	3	0	3	4
Talc, powder	1	0	0	1
Tetrachloroethane	3	0	1	2
Tin, granular (20 mesh)	0	0	0	1
Titanium metal powder (100 mesh)	1	3	2	1
Titanium metal powder (300 mesh)	1	4	2	1
Titanium tetrachloride	3	0	2	3
Trichloroethylene (stabilized)	3	1	2	2
Water	0	0	1	0
Zinc metal powder (dust)	1	3	2	1
Zinc oxide	4	0	3	3