

Reducing Risks to Students and Educators from Hazardous Chemicals in a Secondary School Chemical Inventory

Introduction

The need to properly educate young people in the sciences, especially in chemistry, brings challenges to educators that encompass a vast array of school policies, the safety of the students and faculties, the protection of the environment and associated regulatory compliance issues. The American Chemical Society's Joint Board-Council Committee on Chemical Safety (CCS) was formed to help members understand the importance of safety in the handling and use of chemicals. The Safe Practices Subcommittee of CCS, in preparing this document, examined safety in the handling and use of chemicals as a risk issue to children, as well as educators, in secondary schools only.

The work presented here was based on the following observations and conclusions:

- ACS members who are secondary school educators have requested information regarding aging chemical inventories and appropriate chemicals for secondary school education.
- Chemical inventories found in high schools contain a vast array of chemicals ranging from safe and suitable for education at the secondary level to extremely hazardous, unsuitable and inappropriate for those unknowledgeable or untrained in their use and potentially harmful to the environment.
- The secondary school populations represent our finest young minds and also our least knowledgeable and skilled in laboratory science.
- It is important that our students receive a solid education in chemical science that can only be achieved by using chemicals in the laboratory through safe and effective laboratory experiences.
- Minimizing risks to students from extremely hazardous chemicals at this early stage of science learning is a prudent approach in the educational process.
- There are a number of chemical classification schemes designed to alert users about the uses and hazards of a vast array of chemicals. The Committee agreed that the Globally Harmonized System (GHS) developed by the United Nations (See Appendix A, Reference 8) is appropriate to evaluate the safety and utility of most chemicals in most settings.

The Safe Practices Subcommittee undertook the task of compiling a partial list of chemicals that it believes should not be found in a secondary school chemical inventory or used by individuals who are not knowledgeable and skilled in working with high-hazard chemicals.

Recommendations:

- It should always be the practice of those using chemicals in their laboratories to minimize risks from exposures while at the same time recognizing the benefits of proper educational use of chemicals.
- Chemistry education plans should be developed, reviewed periodically and approved on a regular basis ensuring that:
 - Chemicals utilized in experiments and demonstrations are appropriate to the plan and safe for student use.
 - Students are trained in the proper use of personal protective equipment (PPE).
 - Students are trained in the environmental impact of chemicals.
- Chemicals classified as extremely or very hazardous by the GHS (Hazard Class 1 or HC1) or could be used as illegal drug precursors should not be stored, used by, nor available to high school students. These chemicals include explosives, carcinogens, mutagens, teratogens, etc. If needed to educate students, these chemicals should be handled or used only by science educators who are fully trained in their safe handling for demonstrations or in preparation of dilute solutions, such as the dilution of concentrated acids.
- Maintain chemicals in appropriate storage areas (i.e., stockrooms, cabinets, lockers):
 - Store minimum quantities of chemicals approved in the chemistry or science education plan
 - Restrict access to storage areas by students
 - Prohibit storage of HC1 chemicals, except as needed for demonstrations (demonstration quantities) by educators trained in their use
- Conduct demonstrations safely by:
 - Utilizing appropriate safety precautions (e.g., PPE, ventilation).
 - Only using the minimum quantities of chemicals necessary for the demonstration.

List of Suggested Restricted-Use Chemicals

The list that is presented is not intended to be a comprehensive list of chemicals that should not be found in a secondary school inventory nor is it an attempt to “ban” or otherwise prohibit the proper use of chemicals in the secondary school laboratory. It is provided here as a resource for the secondary school instructor. The American Chemical Society’s Committee on Chemical Safety strongly urges all high school instructors to make a complete chemical inventory and determine what is needed for teaching and what is simply waste which should be properly disposed of as hazardous waste.

Abbreviations used in the table:

abs – absorption (skin)

CNS – Central Nervous System

IARC – International Agency for the Research on Cancer

ing – ingestion

inh – inhalation

NTP – National Toxicology Program

resp – respiratory

RA – Reasonably Anticipated to be a Carcinogen (NTP designation)

rxn – reaction

Chemical	CAS Number	Relevant Hazard
Acetal	105-57-7	Forms explosive peroxides without concentration
Acetic Anhydride	108-24-7	Poison (inh, ing), Irritant (skin, eyes, resp). Violent rxn with many compounds, used in illicit drug manufacturing
Acetonitrile	75-05-8	Toxic (Inh, ing, abs)
Acetyl Bromide	506-96-07	Irritant (skin, eyes, resp); violent rxn with water
2-acetylaminofluorene	53-96-3	Carcinogen
Acetyl Chloride	75-36-5	Irritant (resp), toxic; violent rxn with water
Acrylamide (IARC 2B)	79-06-1	Neurotoxin; carcinogen; toxic (abs).
Acrylonitrile (IARC 2A)	107-13-1	Poison (inh, ing, abs), carcinogen
Adipoyl Chloride	111-50-2	Violent rxn with water; irritant (ing, inh, skin); corrosive
Allyl Chloride	107-05-1	Irritant (skin, resp, eye)
Aluminum Chloride, Anhydrous	7446-70-0	Violent rxn with water
4 -Aminodiphenyl	92-67-1	Carcinogen
Ammonia, Gas	7664-41-7	Corrosive, Irritant (skin, eyes, resp), used in illicit drug manufacturing
Ammonium Bifluoride	1341-49-7	Corrosive; poison (inh, ing, abs)
Ammonium Chromate	7788-98-9	Oxidizer; carcinogen (Cr(VI))
Ammonium Dichromate	7789-09-5	Oxidizer; poison (inh, abs) carcinogen (Cr(VI))
Ammonium Nitrate	6484-52-2	Oxidizer; forms explosive mixtures with hydrocarbons
Ammonium Perchlorate	7790-98-9	Explosive; Oxidizer
Ammonium Sulfide	12135-76-1	Poison (ing)
Ammonium Vanadate	7803-55-6	Poison (inh, ing)
Aniline	62-53-3	Poison (ing, abs); Irritant (eye, skin)
Aniline Hydrochloride	142-04-1	Toxic (ing).
Antimony, Powder	7440-36-0	Dust fire/explosion hazard; contact with acid forms SbH ₃ ; Poison (inh, ing)
Antimony Trichloride	10025-91-9	Corrosive; water reactive; violent rxn with Al, Na, K.
Anthracene	120-12-7	Allergen (skin), Irritant (skin)
Arsenic and its compounds	N/A	Carcinogen
Arsine	7784-42-1	Poison (inh, ing); carcinogen
Asbestos	1332-21-4	Carcinogen
Azide Compounds (i.e., Sodium Azide)	N/A	Explosive. May be fatal if ingested or absorbed through the skin.

Chemical	CAS Number	Relevant Hazard
Barium Chromate	10294-40-3	Carcinogen (Cr(VI))
Benzene	71-43-2	Carcinogen
Benzidine	92-87-5	Carcinogen
Benzoyl Nitrate	6786-32-9	Unstable compound. Explosive decomposition in water; heat & light sensitive explosive.
Benzoyl Peroxide	94-36-0	Oxidizer; sensitizer; allergen (skin)
Beryllium and its Compounds	N/A	Carcinogen
bis (2-chloroethyl)ethylamine	538-07-8	Poison (inh)
bis (2-chloroethyl) sulfide	505-60-2	Carcinogen
Black Powder	-	Explosive
Boron Trichloride	10294-34-5	Violent rxn with water; poison (inh).
Bromine	7726-95-6	Oxidizer; Corrosive; violent rxn with several compounds
Bromoform	75-25-2	Irritant (skin, eyes, resp); lachrymator; poison (ing).
1,3-Butadiene	106-99-0	Peroxide formation w/o concentration; carcinogen
Cadmium and its Compounds	N/A	Carcinogen
Calcium Carbide	75-20-7	Dangerous when wet (liberates acetylene).
Calcium Cyanide	592-01-8	Poison (inh, ing)
Carbon Disulfide	75-15-0	Extremely flammable; Acute CNS/peripheral toxin; reproductive toxin
Carbon Monoxide	630-06-0	Toxic
Carbon Tetrachloride (IARC 2B, NTP RA)	56-23-5	Carcinogen. Acute renal/hepatotoxin.
Carbonyl sulfide	463-58-1	Violent rxn with oxidizers; Toxic (inh, ing).
Chloral Hydrate	302-17-0	DEA controlled substance
Chlorine	7782-50-5	Oxidizer, corrosive; irritant (inh); poison (inh).
Chlorine Trifluoride	7790-91-2	Powerful oxidizer; explosive rxn with water, acids; poison (inh)
Chloroform (IARC 2B, NTP RA)	67-66-3	Carcinogen
bis-chloromethyl ether	54-28-81	Carcinogen
Chloroprene	126-99-8	Poison (ing); irritant (resp); flammable, explosive; violent self-polymerization in air
Chloropromazine	50-53-3	Controlled substance

Chemical	CAS Number	Relevant Hazard
Chlorosulfonic Acid	7790-94-5	Oxidizer; corrosive; irritant (skin, eyes, resp)
Chromic Acid	7738-94-5	Carcinogen (Cr(VI))
Chromium Hexavalent Compounds	N/A	Carcinogen
Chromium Trioxide	1333-82-0	Carcinogen
Colchicine	64-86-8	Poison (ing),
Collodion	9004-70-0	Explosive when dry
Cuprous Cyanide	544-92-3	Poison (inh, ing, abs)
Cyanogen Bromide	506-68-3	Corrosive; Poison (inh, ing, abs)
Cyanogen Chloride	506-77-4	Poison (ing); toxin (inh); irritant (eye); lachrymator
Cyclohexene	110-82-7	Flammable; Forms peroxides
Diaminotrinitrobenzene	1630-08-6	Highly explosive
1,2-dibromo-3-chloropropane	96-12-8	Carcinogen
p-Dichlorobenzene (IARC 2B, NTP RA)	106-46-7	Carcinogen
3,3'-dichlorobenzidine (and salts)	91-94-1	Carcinogen
4-dimethylaminoazobenzene	60-11-7	Carcinogen
Dimethylaniline	121-69-7	Poison (inh, ing, abs)
Dimethylsulfoxide	67-68-5	Rapidly absorbed through skin, allowing absorption of contaminants
Dinitrophenol	25550-58-7	Explosive
2,4-Dinitrophenylhydrazine	119-26-6	Explosive
p-Dioxane (IARC 2B, NTP RA)	123-91-1	Forms peroxides; carcinogen
Ethanolamine	41-43-5	Irritant (skin, eyes; resp); violent rxn with acids.
Ethyl Ether	60-29-7	Forms peroxides
Ethylene Dichloride (1,2-Dichloroethane)	107-06-2	Toxic (inh, ing).
Ethyleneimine	15-15-64	Sensitizer (skin).
Ethylene Oxide	75-21-8	Explosive; Poison (ing, abs) carcinogen
Ferrous Sulfide	1317-37-9	Water reactive
Fluorine	7782-41-4	Powerful oxidizing agent; poison (inh, ing, abs).
Formaldehyde (Formalin)	50-00-0	Carcinogen
Gunpowder	N/A	Explosive
Hexachlorophene	70-30-4	Poison (ing)

Chemical	CAS Number	Relevant Hazard
Hydrazine (IARC 2B)	302-01-2	Powerful reducing agent; explosive; corrosive; carcinogen
Hydrofluoric Acid and solutions containing HF	7664-39-3	Corrosive; May be fatal if inhaled or ingested (liquid and vapor can cause severe burns not always immediately painful or visible but possibly fatal)
Hydrogen	1333-74-0	Flammable gas
Hydrogen Bromide (anhydrous)	10035-10-6	Poison (inh); corrosive
Hydrogen Chloride (anhydrous)	7647-01-0	Poison (inh); corrosive
Hydrogen Sulfide, Gas	7783-06-4	Poison (inh); flammable
Isopropyl Ether	108-20-3	Forms explosive peroxides
Lead Arsenate	7784-40-9	Carcinogen; teratogen
Lead Azide	13424-46-9	Poison (ing); explosive
Lead Carbonate	598-63-0	Poison (inh, ing)
Lead (VI) Chromate	7758-97-6	Carcinogen
Lithium Aluminum Hydride	16853-85-3	Powerful reducing agent, violent rxn with many compounds
Lithium, Metal	7439-93-2	Water reactive
Lithium Nitrate	7790-69-4	Oxidizer
Magnesium, Metal	7439-95-4	Water reactive; violent rxn with many compounds
Mercuric Compounds	N/A	Neurotoxic
Mercury	7439-97-6	Poison (inh)
Methyl Bromide	74-83-9	Poison (inh)
Methylchloromethyl ether (IARC 1)	10-73-02	Carcinogen
Methylene Chloride (IARC 2B, NTP RA)	75-09-2	Poison (inh, ing, abs); carcinogen
Methyl Ethyl Ketone	78-93-3	Toxic (inh, ing, abs); used in illicit drug manufacture
Methyl Isocyanate	624-83-9	Poison (ing, ing, abs); irritant (skin, eye); sensitizer
Methyl Isopropyl Ketone	563-80-4	Poison (ing); irritant (skin, eye)
Methyl Mercaptan	74-93-1	Poison (inh)
Methyl Methacrylate	80-62-6	Violent polymerization in air
-Naphthylamine	14-23-27	Carcinogen
-Naphthylamine	91-59-8	Combustible; Known human carcinogen

Chemical	CAS Number	Relevant Hazard
Nitric Oxide	10102-43-9	Corrosive; poison (inh); irritant (skin, eye, resp)
Nitritotriacetic Acid (IARC 2B, NTP RA)	139-13-9	Carcinogen
Nitrobenzene	98-95-3	Poison (inh, ing, abs)
4-Nitrobiphenyl	92-933	Carcinogen
N-nitrosodimethylamine	62-75-9	Carcinogen
Nitrocellulose	9904-70-0	Explosive; flammable
Osmium Tetroxide	20816-12-0	Corrosive; Poison (ing, ing, abs)
Paris Green	12002-03-8	Poison (ing, abs)
Perchloric Acid	7601-90-3	Powerful oxidizer when hot; violent rxn with many compounds when hot
Phosphorus Pentasulfide	1314-80-3	Water reactive; poison (ing); irritant (skin, eye)
Phosphorus Pentoxide	1314-56-3	Water reactive; corrosive; poison (ing), irritant (skin, eye, resp), violent rxn with many compounds
Phosphorus Trichloride	7719-12-2	Poison (ing, ing); corrosive; violent rxn with many compounds
Potassium Cyanide	151-50-8	Poison (inh, ing, abs)
Potassium, Metal	7440-09-7	Flammable; Water reactive; Forms peroxides
Potassium Perchlorate	7778-74-7	Strong oxidizer
Potassium Sulfide	1312-73-8	Spontaneously combustible; explosive in dust or powder form; poison (inh, ing)
-propiolactone (IARC 2B)	57-57-8	Carcinogen
Pyrogalllic Acid	87-66-1	Corrosive; poison (ing); irritant (skin)
Silicon Tetrafluoride	7783-61-1	Poison (inh); irritant (skin, eyes, resp)
Silver Cyanide	506-64-9	Poison (inh, ing, abs)
Silver Nitrate	7761-88-8	Oxidizer; corrosive; may be fatal if ingested; poison (ing); incompatible with many compounds
Sodium Arsenate	7778-43-0	Carcinogen, poison (inh, ing)
Sodium Arsenite (IARC 1)	7784-46-5	Carcinogen; teratogen
Sodium Azide	26628-22-8	Explosive with many metals, poison (ing, abs)
Sodium Borohydride	16940-66-2	Water reactive; corrosive; irritant (eye, skin), violent rxn with many compounds
Sodium Chromate	7775-11-3	Oxidizer; corrosive; carcinogen (Cr(VI))
Sodium Cyanide	143-33-9	Poison (inh, ing, abs)
Sodium Dichromate	10588-01-9	Carcinogen (Cr(VI))
Sodium Fluoride	7681-49-4	Poison (inh, ing, abs)
Sodium Fluoroacetate	62-74-8	Poison (ing, abs)
Sodium Peroxide	1313-60-6	Oxidizer, water reactive; corrosive

Chemical	CAS Number	Relevant Hazard
Sodium Sulfide	1313-82-2	Poison (ing); spont. combustible
Sodium Thiocyanide	540-72-7	Poison (ing)
Stannic Chloride	7646-78-8	Water reactive; corrosive; irritant (skin, eye)
Strontium	7440-24-6	Water reactive
Testosterone	58-22-0	Controlled substance
Tetrabromoethane	79-27-6	Poison (inh, ing, abs)
Tetrafluoroethylene	116-14-3	Forms explosive peroxides
Tetrahydrofuran	109-99-9	Forms explosive peroxides
Thioacetamide (IARC 2B, NTP RA)	62-55-5	Carcinogen
Thionyl Chloride	7719-09-7	Violent rxn with water; corrosive; poison (ing, abs)
Thiourea (IARC 2B, NTP RA)	62-56-6	Carcinogen
Titanium (III) chloride	7705-07-9	Violent rxn with water; spont, combustible in air; irritant (skin, eyes); corrosive
o-Toluidine (IARC 2B, NTP RA)	95-53-4	Carcinogen
Trimethylamine	75-50-3	Flammable
1,3,5-Trinitrobenzene	99-35-4	Explosive; poison (ing)
Trinitrophenol (Picric Acid)	88-89-1	Poison (ing); irritant (skin, eye), allergen; unstable, explosive when dry
2,4,6-Trinitrotoluene	118-96-7	Explosive
Urethane (IARC 2B)	51-79-6	Carcinogen
Vinyl Ether	109-93-3	Readily forms explosive peroxides, hypergolic with nitric acid
Vinyl Chloride (IARC 1)	75-01-4	Carcinogen
Wood's Metal	8049-22-7	Carcinogen (Cadmium); neurotoxic

Appendices

Appendix A: United Nations Global Harmonized System and the Criteria for Selection

The United States has been part of the process to develop a global system of hazardous chemical classification. This Global Harmonized System (GHS) developed criteria for identifying the relative risk of various hazardous chemicals. The highest class of those chemicals is known as HC1 (Hazard Class 1) and it is composed of the most hazardous chemicals that pose extreme risks from physical (flammability; reactivity) and/or health hazards (acute and chronic toxicities) of these chemicals if exposure should occur. The details of GHS and the description of HC1 chemicals can be found at:

http://www.unece.org/trans/danger/publi/ghs/ghs_rev02/02files_e.html

Selection criteria:

- This list was compiled using the best available toxicological and physical property data.
- The chemicals listed as “HC1” chemicals as defined by the Global Harmonized System (GHS) should be considered as examples only, not a complete comprehensive list. In this “all-hazard” system, the *highest hazards* have the *lowest numbers*, with 1 being the most hazardous. The chemicals in this list pose extreme physical hazards (such as flammability or reactivity) or extreme health hazards (such as acute toxicity or carcinogens). GHS is currently in wide use throughout Europe and Asia, and the United States is moving to adopt GHS in its hazard communication standards.
- Inclusion criteria incorporated, but were not limited to, the following four factors:
 - Physical hazards (i.e., flammability, reactivity)
 - Health hazards (i.e., toxicological properties)
 - Carcinogenicity, IARC Group 1 or 2A. *IARC Group 2B chemicals were included only if they are also listed as Reasonably Anticipated carcinogens by the National Toxicology Program, 11th Report on Carcinogens.*
 - Potential use as an illegal drug precursor, or otherwise regulated by the Drug Enforcement Agency.

Appendix B. References

1. Bretherick, L., *Hazards in the Chemical Laboratory*, 3rd ed. Royal Society of Chemistry, London, 1981.
2. Patnaik, P., *A Comprehensive Guide to the Hazardous Properties of Chemical Substances*, 3rd ed. John Wiley & Sons, Hoboken, NJ, 2007.
3. Lewis, R., *Hawley's Condensed Chemical Dictionary*, 12th ed. Von Nostrand Reinhold Company, New York, 1993.
4. Urben, P.G. (Ed.), *Bretherick's Handbook of Reactive Chemical Hazards*, 6th ed., Butterworth-Heinemann, Oxford. 1999.
5. Lewis, R. *Sax's Dangerous Properties of Industrial Materials*, 10th ed. John Wiley and Sons, 1999.
6. International Agency on the Research on Cancer Monographs. Various years. International Agency on the Research on Cancer. www.iarc.org. Accessed May 2008.
7. Report on Carcinogens, Eleventh Edition; US Department of Health and Human Services; Public Health Service, National Toxicology Program, 2005.
8. United Nations Global Harmonization System, http://www.unece.org/trans/danger/publi/ghs/ghs_rev02/02files_e.html, UN Economic Commission for Europe, Information Service, Palais des Nations, CH - 1211 Geneva 10, Switzerland