Heavy Metals, their Salts, and other Compounds

A Quick Reference Guide from AIC and the Health & Safety Committee

A Special Insert By

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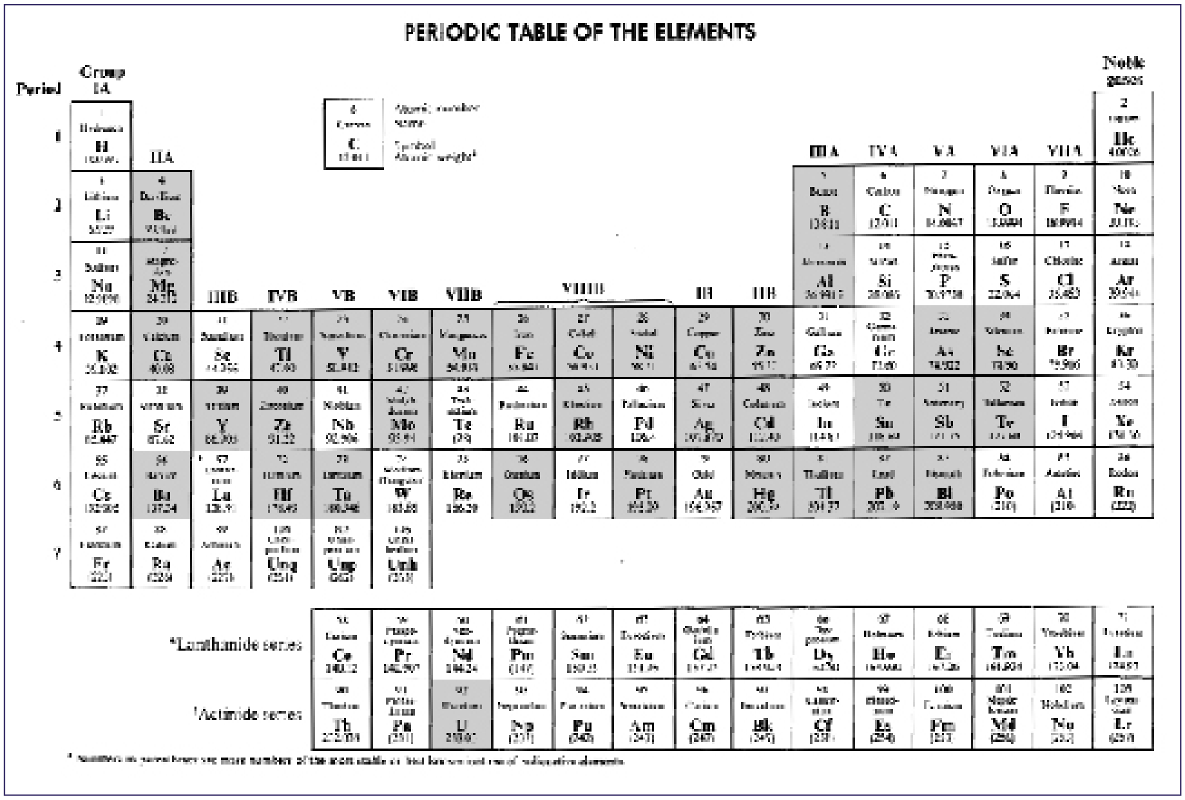

Figure 1. The 35 shaded elements in this periodic table are those regulated by OSHA under the classification of Heavy Metals [1, 2].

Introduction

The term heavy metal is a loosely used term generally accepted to mean dense metals of relatively high atomic mass, with a specific gravity of 4 or above. Although there are several other definitions of the term there is no specific set of elements that would imply any common set of properties such as high toxicity or high atomic weight [3]. The heavy metals group includes transition metals, some metalloids (elements that exhibit both metal and non-metal properties), some lanthanides and actinides, and often includes reference to certain light and trace metals with an inference to toxicity. An example of the ambiguity of the term heavy metal is that of molybdenum, a heavy but essential trace element and beryllium, a light but very toxic metal [4]. All metals are characterized by their excellent ability to conduct heat and electricity (the metalloids being semi-conductors), and are malleable, ductile, hard, and shiny, the exception being mercury which is liquid at room temperature.

One of the most significant factors about metals is their residual persistence over time. Metallic compounds such as oxides, sulfides, chlorides, carbonates, nitrates, and other salts are formed when positively charged metals called cations react with negatively charged elements called anions in ionic or covalent bonds. The resulting metallic compounds can result in very different properties of solubility and toxicity [5]. For example, trivalent chromium, Cr (III), is an essential trace element [6] and its compounds, including soluble chromium salts, are considered to be of low toxicity and are thought to present few industrial hazards [22]. Hexavalent chromium, Cr (VI), however, is highly toxic [6] and its compounds, including chromic acid and chromates, are potential carcinogens [22].

Posted on the AIC website, the "Chart of Heavy Metals, their Salts, and other Compounds" provides a quick reference to the 35 elements and some of their compounds classified and regulated by OSHA as heavy metals [1]. Additional compounds often encountered in conservation are also listed. The guide is not definitive or all-inclusive; it is meant to be used in conjunction with other resources. Complete information about each of their properties, toxicity, and specific compound or additional occupational exposure levels can be found in MSDS sheets, OSHA and NIOSH publications, and other health and regulatory governing agencies found on the Internet and listed at the end of this guide. All health and safe handling guidelines and hazardous waste disposal should be followed as outlined by the various governing bodies; appropriate personal protective equipment (PPE) should be used as described in OSHA regulations with particular attention paid to the use of respirators.

Detection Methods

The appropriate testing method to use for the detection of a specific heavy metal will depend on the answers to some key questions:

- What do you want to know and why?
- What is the material type of the object to be tested?
- Can a sample be taken or must the test be non-destructive?

Regardless of the testing method, test results on homogeneous samples are usually indicative of the entire object, however, results on heterogeneous samples (such as organic substrates) are indicative of the specific test site/sample only. Quantitative results are relevant only for the sample or site tested.

Spot Tests

Spot test procedures are relatively reliable indicators of the presence of residual surface chemicals. They can provide results ranging from qualitative to semi-quantitative. Some tests are available in pre-packaged test kits. Spot tests can be destructive or non-destructive to the object or surface being tested depending on the method used. They all involve chemical reactions and need to be conducted in a safe controlled environment whether in the laboratory or in the field by trained personnel. Proper waste disposal guidelines for hazardous waste generated from the test procedure should be followed [7, 8].

Analytical Instruments

Hand-held X-ray Florescence Spectrometry (XRF) - A surface technique, the XRF analyzer conducts multiple elemental analyses and is considered to be non-destructive to the object. It can be used with swabs, wipes, or in direct contact with the surface. The instrument yields quantitative results for modern metal alloys or soils based on approved NIST industrial standards and calibrations for which the instruments were made. Results on archaeological metals and glass substrates range from qualitative to quantitative; results on organic substrates are presently qualitative, but with appropriate reference materials, instrument calibrations may be able to offer semi-quantitative ranges. The instrument is easy to use but spectrum and data are complicated to interpret, especially on organic substrates because the data alone cannot be relied on for accurate results and spectrum must be interpreted. Trained personnel are necessary for application and accurate interpretation. The hand-held XRF is an excellent screening tool and can easily be used in storage rooms and exhibition cases, as well as on-site for field archaeology.

Inductively Coupled Plasma Spectroscopy (ICP) - Conducts multiple elemental analyses using a tiny sample that must be dissolved for the analysis (a destructive technique). Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (La-ICP-MS) models have the capability to analyze certain whole objects. The instrument yields highly accurate quantitative results for low levels of elements. It is an excellent tool to crosscheck semi-quantitative to quantitative results of the hand-held XRF [9]. ICP is a laboratory procedure that must be conducted by qualified personnel [7, 10, 11].

Atomic Absorption Spectroscopy (AAS) - Analyzes one element at a time using a tiny sample that must be dissolved for the analysis (a destructive technique). The instrument yields highly accurate quantitative results for low levels of elements. The use of High Performance Liquid Chromatography (HPLC) in conjunction with AAS analysis (used as the detector) can provide speciation of the sample [12.] AAS is a laboratory procedure that must be conducted by qualified personnel [7, 10, 11].

Spark Emission Spectroscopy - A destructive technique that tests mostly solids and is good for bulk constituents [7].

Wet Chemical Techniques - Samples must be dissolved (destructive techniques). Wide variety of possible techniques, titrations, ion-specific electrodes, etc; may be very useful depending on the analyte and levels to be analyzed [7].

Ion Chromatography - Low levels (range of 0.1 ppm) of multiple ions can be determined giving quantitative results. The samples must be dissolved making it a destructive technique [7, 10].

Health and Safety

Unlike industrial workers who are more likely to encounter higher doses of potentially hazardous materials resulting in acute exposure [13], museum workers are more likely to be exposed to low-level doses of

List of Acronyms

For a comprehensive lists of acronyms, health agencies and governing bodies refer to the following websites:

ACGIH: American Conference of Governmental Industrial Hygienists, www.acgih.org

CDC: Center for Disease Control and Prevention, www.cdc.gov

DHHS: U.S. Department of Health and Human Services, www.os.dhhs.gov

EPA: U. S. Environmental Protection Agency, www.epa.gov

OSHA: Occupational Safety and Health Administration, www.osha.gov

NIOSH: National Institute for Occupational Safety and Health, www.cdc.gov/niosh

Acronyms used in the chart and references:

CAS: Chemical Abstract Service (chemical registry number)

MSDS: Material Safety Data Sheets

PEL: Permissible exposure limit - OSHA regulated concentrations

TLV: Threshold limit value - ACGIH suggested concentration guidelines

TWA: Time-weighted average - NIOSH recommended exposure limits (RELs)

ppm: parts per million (conversion factors: parts of vapor or gas per million parts of contaminated air by volume at 25°C and 1 atmosphere)

mg/m3: milligrams per cubic meter (conversion factors: milligrams of vapor or gas per cubic meter of contaminated air at 25°C and 1 atmosphere) heavy metals over an extended period of time, resulting in chronic health problems. Heavy metal exposure in the environment along with that from museum collections and buildings is of particular concern to museum professionals involved in emergency and disaster rescue and recovery efforts. Health and safe handling guidelines for specific metals and their compounds have been developed by national and international governing health and environmental agencies and are readily available in electronic form and in numerous hardcopy publications. Institutions in the U.S. are required to follow OSHA health and safety regulations and dispense all known information about existing hazards to personnel and handlers of the materials under OSHA's 1986 Hazard Communication Standard providing employees with the right to know [7].

Personal Protective Equipment (PPE) - Consult OSHA regulations, NIOSH recommendations, and MSDS sheets as well as other resources pertaining to specific PPE required for use with certain hazardous materials and standard lab procedures. Nitrile gloves, lab coats, booties, hair nets, protective suits, dust masks and respirators are standard PPE for use in conservation laboratories. Respirator use is governed by OSHA [14]. Those who need/ choose to use respirators must obtain medical clearance, receive use training and have their respirator individually fit tested by authorized testers prior to use. Members of the Health & Safety Committee provide training and fit testing at the annual AIC meetings. All respirators must be NIOSH approved for the specific type of mask, filter, or cartridge needed [14, 15].

Handling and Storage - In general, most objects containing hazardous materials should be kept in a tightly closed container, stored in a cool, dry, ventilated area, isolated from any source of heat or ignition and in an area where it will be protected against physical damage. Do not use or store hazardous materials on porous work surfaces (wood, unsealed concrete, etc.). Follow strict hygiene practices. Containers may be hazardous when empty since they can retain product residues (dust, solids, vapors, liquid); observe all warnings and precautions listed for the product. Dispose of containers and unused contents in accordance with federal, state and local requirements [16]. Laboratory safety protocol should be followed. MSDS documents must be on the premises in the lab for each substance present. Unless a substance is known to not be hazardous, it should be treated as though it was hazardous.

Documentation- All test results, suspect hazards and known archival information should be documented (written, photo, analytical test results) and filed appropriately (electronically/ hard copy) for easy access by personnel who handle the material. All tested objects, shelves, drawers, and storage room doors should be identified as having been tested with clear and concise hazard identification labels or tags, and for an individual item, both the object and the container (polyethylene bag, box) and/or isolated shelf or drawer should be labeled.

A Specific Note About Mercury

Inhalation of mercury vapor is of particular concern if working in an enclosed, not well-ventilated room. Therefore, it is suggested that personnel not work in certain storage areas or the confines of an exhibit case. To retrieve an object suspected or known to be fabricated or contaminated with a mercury compound, it is suggested that the drawer or cabinet where the object is housed be opened and that individuals immediately leave the room for a period of time* without breathing in the air directly in front of or above the housing unit. This will allow any mercury vapor that may have built up in the enclosed drawer or cabinet to be released into the ambient air. Once it is safe to return to the room, remove the object to a well-ventilated area rather than work in the store room if at all possible. The same precaution should be taken when opening an enclosed container to retrieve an object: e.g. open/unseal a bagged object in a fume hood or well-ventilated room, leave the area and return after a period of time* to continue work. When work is completed then re-seal the container before returning it to the store room [8]. All pertinent PPE should be used throughout the process.

**The specific time interval is unknown as it relates directly to the level of airflow and other factors in the room. Air quality tests can be conducted to determine the time frame using a Jerome 431-X Mercury Vapor Analyzer and a Lumex RA-915+ Multifunctional Mercury analyzer [8].*

A Specific Note About Arsenic as Arsine

Possible exposure to arsine for conservators, collection managers and other museum workers is normally confined to controlled chemical reactions such as in the arsenic spot test. In view of the recent natural disasters that have been occurring, museum workers and disaster recovery teams should be aware that arsine gases can also form as a result of the natural (and complex) biomethylation process undertaken by certain organometallic micro-organisms in the environment [17]. Although highly unlikely to be found in environmentally climate-controlled institutions, it is possible that under certain moisture/ high humidity conditions where mold may form, these micro-organisms could be present and this increases the potential of arsine being present [18, 19]. High levels of methylated arsenic compounds have been found in confined spaces in greenhouses and in relation to arsine poisoning incidents involving the pigment, Paris Green (copper acetoarsenite), in wall paper [17, 20]. Arsine has a subtle garlic odor associated with its presence.

An expanded version of the Heavy Metals Reference Guide is available online through the AIC Health & Safety Committee's webpage. This document includes a chart with an extensive listing of OSHA regulated heavy metals, their salts, and other compounds. This handy reference guide details the physical description, use, occupational exposure limits, and chemical formulae of over one hundred compounds. Visit www.aic-faic.org to download a copy for your lab today.

References:

Note: this section is applicable to the printed text and the on-line chart.

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