

In My Computer book proposal - Jonathan Kemp, December 2013

1) Concept

starting from an idea of a play on

\$cat /proc/cpuinfo

and

\$ps -u jonnix --forest

the book explores the speculative command

\$ps -u jonnix --geology

to detail the geophysical component IDs used in production of the processor inside my 2005/6 IBM x60 laptop, according to toxicology and geological distributions.

title:

In my processor

or

\$cat /proc/cpuinfo

or

#process_this!

subtitle:

\$cat /proc/cpuinfo

or

\$ps -u jonnix --geology

contents:

- unpublished chart from IBM senior processor developer showing increase from 7 to 54 in the number of elements used in processors from before the 1990's until 2005, (and including processor used in my IBM x60 laptop)
- 54x periodic element toxicology listings, arranged by atomic weight number
- geological mapping of 54 elements ** nb. incomplete for all 54 elements, reflecting available data from UN, USG, BGS, and private databases
- unpublished correspondence between the author and various agencies about minerals used in computers and processors

Emails over the last two years with computer/processor manufacturers and geological information services confirm a lack of research within the manufacturing, mining, and recycling industries as to just how much and how many minerals are used in a typical computer.

This lack of information is not surprising given the huge chains of production methods, regulations, and resources that lie between say a landscape of raw rock ores and our current sleek laptops. Its just that each particularised industry in the cycle of computer production tends to commission research that somehow benefits only their business.

For example, recyclers spend on research that will help in improving the extraction rates of valuable metals from bulk electronic scrap. And if we scale up from any industry, to government level, then research concerns can get slightly more conspiratorial. Recent US studies examining the supply of rare-earth metals, that is the set of 17 related metals now seen as crucial to miniaturizing computers, have been primarily driven by the US Government's concern that China currently holds up to 95% of their supply.

Where correlations have been made it is by using net energy analysis and life cycle assessments to focus on energy usage in production and the afterlife of the more generic materials used in computers

The proposed book sets out basic information towards making some correlations between industrialised subterranean extractions, and the accelerated development of digital technologies. The 54 periodic elements identified in the manufacture of the processor used in my IBM X60 laptop, on which all the material for the book has been executed and stored, will be detailed according to atomic weight, toxicological, and, where possible, geological information.

2) Bio

Jonathan Kemp has a long history of organising and collaborating speculative and situational events (including as a co-founder of xxxxx).

With others, he has elaborated speculative symposia, performances, installations, and large scale social software events executed in numerous international festivals, venues, and institutions throughout Europe, the US, and Brazil.

Projects are informed by an interest in code-brut reconfigurations of the material substrates of computation, and recent work includes initiating the seminal series of open material processing laboratories, environmental installations, and exhibitions, The Crystal World.

<http://xxn.org.uk>

<http://crystalworld.org.uk/>



Jonathan Kemp <jonathan.kemp@my.westminster.ac.uk>

Minerals used in cpus

CJ [REDACTED] <[\[REDACTED\]@centtech.com](mailto:[REDACTED]@centtech.com)>

3 January 2012 21:02

To: Jonathan Kemp <jonathan.kemp@my.westminster.ac.uk>, support <support@centtech.com>

Cc: [REDACTED] <[\[REDACTED\]@centtech.com](mailto:[REDACTED]@centtech.com)>

Hi Jonathan,

Thanks for contacting us. We're glad to hear from customers or those who are interested in our processors!

Sorry, we do not have a list of such compositions. We rely upon 3rd parties for our wafers, packaging, and assembly, and much of that data is under non-disclosure. However, we do disclose the absence of a particular element, lead, due to RoHS regulations.

Best Regards,

C.J. [REDACTED]

Centaur Technology, a VIA Technologies, Inc company.
[REDACTED]



Jonathan Kemp <jonathan.kemp@my.westminster.ac.uk>

{ticketno:[8000370451]} - Your Intel Customer Support Inquiry

SUPPORT.REPLIES@mailbox.intel.com <SUPPORT.REPLIES@mailbox.intel.com>

2 January 2012 20:36

To: jonathan.kemp@my.westminster.ac.uk

Hello Jonathan,

Thank you for your follow-up request regarding our internal processes.

You are correct. Since information related to your inquiry could not be found in our archives, the sites to which I most recently referred were the result of a cursory examination of the results of an internet search on the terms, "mineral content of microprocessors." I did not carefully examine the nature of the sites listed in the search results. Please accept my sincere apology for providing references unrelated to your question.

All public information that we can provide relating to your inquiry is located on the Intel Web sites to which I referred in my initial reply:

www.intel.com/technology/manufacturing/index.htmhttp://newsroom.intel.com/community/intel_newsroom/blog/2011/11/21/chip-shot-new-from-sand-to-silicon--the-making-of-a-chip-photos-availablewww.intel.com/about/companyinfo/museum/exhibits/sandtocircuits/index.htm<http://educate.intel.com/en/TheJourneyInside>

If you have not already done so, you may want to conduct an Internet search on the terms, "mineral composition of microprocessors" or similar search terms relating to the information you seek.

If there are other datasheets, application notes or photos that the Intel Museum Document Request Service can assist you with, please let me know.

Best regards with your research,

Jim A.

Intel Museum

www.intel.com/content/www/us/en/company-overview/intel-museum.html

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*Other names and brands may be claimed as the property of others.

A representative of Intel may subsequently contact you (by e-mail) in order to obtain your feedback on the quality of the support you received. If you do not want to participate, simply delete the survey e-mail.

Original Text

From: jonathan.kemp@my.westminster.ac.uk**To:** support.replies_@mailbox.cps.intel.com**CC:****Sent:** 12/25/11 15:47:35**Subject:** Re: {ticketno:[8000370451]} - Your Intel Customer Support Inquiry

Dear Jim A

Please can you confirm your status as it appears you have made some (algorithmic) errors in processing my request:

- a) my request is about the minerals used in Intel cpus/processors
- b) the links you have sent are for a gaming site and the processors and minerals therein are fictitious!

If possible please upstream my enquireis

Kind Regards

Jonathan

On 23 December 2011 16:10, <SUPPORT.REPLIES@mailbox.intel.com> wrote:

Hello Jonathan,

Thank you for your follow-up request regarding our internal processes.

All information that we have that is available to the public can be located on the Web sites to which I referred in my previous e-mail.

I could not locate information pertaining to your inquiry in our archives. However, I did locate information for you on the following Web sites**:

<http://www1.eveinfo.com/item/MID18-475-780-781-909-1021-1023-1035-65-805-11538/minerals/construction-components/manufacture-research/station-components/capital-ship-components/minmatar/takmahl/outpost-improvement-platforms/caldari-improvement-platforms/components/nanomechanical-microprocessor.html>

<http://www1.eveinfo.com/item/MID18-475-807-1021-1024-1035-65-802-11539/minerals/construction-components/manufacture-research/amarr/artifacts-and-lore/outpost-improvement-platforms/gallente-improvement-platforms/components/nanoelectrical-microprocessor.html>

If there are other datasheets, application notes or photos that we can assist you with, please let me know.

Best regards,

Jim A.

Intel Museum

www.intel.com/content/www/us/en/company-overview/intel-museum.html

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*Other names and brands may be claimed as the property of others.

**Please note that Intel can neither vouch for nor recommend any third party vendor or Web site. We offer this information only as a courtesy.

A representative of Intel may subsequently contact you (by e-mail) in order to obtain your feedback on the quality of the support you received. If you do not want to participate, simply delete the survey e-mail.

Original Text

From: jonathan.kemp@my.westminster.ac.uk

To: support.replies_@mailbox.cps.intel.com

CC:

Sent: 12/22/11 09:41:10

Subject: Re: {ticketno:[8000370451]} - Your Intel Customer Support Inquiry

Dear Jim

Many thanks for the links that you sent.

From an academic point of view only I am interested in a bit more detail such as the actual minerals used in a processor and how much of each %-wise.

For example, I wonder if it's possible to see any qualitative breakdown of what % silicon, silver, copper and any other dopant contents (unnamed in the links supplied) there are on say a Core Duo processor?

I'm also interested in the wider aspect of qualitatively what minerals are used in an average desktop PC as there has been little published work on such a question - the most recent studies (two from 1996, one updated 2001) suggest between 40 and 66 minerals are used - I'd really appreciate any further help you can give from within Intel.

Best Wishes

Jonathan

On 22 December 2011 02:45, <SUPPORT.REPLIES@mailbox.intel.com> wrote:

Hello Jonathan,

Thank you for your interest in Intel and for your inquiry regarding our internal processes.

All information available to the public can be located on our Web sites listed below:

www.intel.com/technology/manufacturing/index.htm

http://newsroom.intel.com/community/intel_newsroom/blog/2011/11/21/chip-shot-new-from-sand-to-silicon--the-making-of-a-chip-photos-available

www.intel.com/about/companyinfo/museum/exhibits/sandtocircuits/index.htm

<http://educate.intel.com/en/TheJourneyInside>

If you have questions or require further assistance, please let me know.

Best regards with your research project,

Jim A.

Intel Customer Support

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*Other names and brands may be claimed as the property of others.

A representative of Intel may subsequently contact you (by e-mail) in order to obtain your feedback on the quality of the support you received. If you do not want to participate, simply delete the survey e-mail.

*****PLEASE DO NOT DELETE*****

Your service ticket reference number is: {ticketno:[8000370451]}

You must include this text in any reply to this email. Thank you.

*****PLEASE DO NOT DELETE*****

Original Text

From: jonathan.kemp@my.westminster.ac.uk

To: channelfb_@mailbox.cps.intel.com

CC:

Sent: 12/20/11 06:54:47

Subject: Contact Intel

reqfields: Form Subject,Comment,First Name,Last Name,Country,email

formtable: corporateproblem_fb

subject: Contact Intel

resulturl: <http://www.intel.com/about/companyinfo/thankyou.htm>

Form Subject: Computer materiality: Desktop Computers/Intel® Core Duo processor - minerals used in manufacturing

Comment: Hello

I'm working on a project about the materiality of computers - there is very little information available in the public domain, with only two or three rough and ready quantifications available from the late 1990's.

If possible I wonder if you have any information on what/how much minerals are used in a standard computer? Furthermore, I'm interested in the material make-up of the various components of a computer - so, for example, the online guide to the manufacture of the Duo processor indicates some of the materials used but not explicitly all those used - would this information also be available to consult?

Yours Sincerely

Jonathan Kemp

First Name: Jonathan

Last Name: Kemp

Country: UK

email: jonathan.kemp@my.westminster.ac.uk

submit: Submit

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Ph.D Researcher in Experimental Media

<http://xxn.org.uk>

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Ph.D Researcher in Experimental Media

The following information was generated from the Hazardous Substances Data Bank (HSDB), a database of the National Library of Medicine's TOXNET system (<http://toxnet.nlm.nih.gov>) on December 12, 2013.

Query: The chemical name hafnium was identified.
The following terms were added from ChemIDplus:
celtium
CAS Registry Number: 7440-58-6

1

NAME: HAFNIUM, ELEMENTAL

HSN: 552

RN: 7440-58-6

NOTE:

This record contains information for hafnium in its zero valence state only. For general toxicity and environmental fate of hafnium ions and hafnium compounds, refer to the HAFNIUM COMPOUNDS record.

HUMAN HEALTH EFFECTS:

HUMAN TOXICITY EXCERPTS:

/SIGNS AND SYMPTOMS/ Lungs may be affected by repeated or prolonged exposure. The substance may have effects on the liver.[IPCS, CEC; International Chemical Safety Card on Hafnium. (October 1995). Available from, as of June 10, 2005:
<http://www.inchem.org/documents/icsc/icsc/eics0847.htm>] **PEER REVIEWED**

/SIGNS AND SYMPTOMS/ Overexposure to hafnium and its compounds may cause mild irritation of the eyes, skin, and mucous membranes.[OSHA; Health Guidelines, NIOSH/OSHA/DOE for Hafnium (7440-58-6). Available from, as of July 13, 2005:

<http://www.osha.gov/SLTC/healthguidelines/hafnium/recognition.html#exposuresources>]

PEER REVIEWED

SKIN, EYE AND RESPIRATORY IRRITATIONS:

Hafnium and its compounds are mild irritants of the eyes, skin, and mucous membranes. No industrial poisonings involving hafnium have been reported.[OSHA; Health Guidelines, NIOSH/OSHA/DOE for Hafnium (7440-58-6). Available from, as of July 13, 2005:

<http://www.osha.gov/SLTC/healthguidelines/hafnium/recognition.html#exposuresources>]

PEER REVIEWED

Irritant /to/ eyes.[Bingham, E.; Cohrssen, B.; Powell, C.H.; Patty's Toxicology Volumes 1-9 5th ed. John Wiley & Sons. New York, N.Y. (2001)., p. V2 p.725] **PEER REVIEWED**

MEDICAL SURVEILLANCE:

Routine medical examinations should be provided to each employee who is exposed to hafnium and compounds at potentially hazardous levels. The employer should screen employees for history of liver disease. ... The importance of this organ in the biotransformation and detoxification of

foreign substances should be considered before exposing persons with impaired liver function. Only those giving a positive history of these conditions should be referred for further medical examinations.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED**

EMERGENCY MEDICAL TREATMENT:

EMERGENCY MEDICAL TREATMENT:

EMT COPYRIGHT DISCLAIMER:

The information contained in the Truven Health Analytics Inc. products is intended as an educational aid only. All treatments or procedures are intended to serve as an information resource for physicians or other competent healthcare professionals performing the consultation or evaluation of patients and must be interpreted in view of all attendant circumstances, indications and contraindications.

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LIFE SUPPORT:

- o This overview assumes that basic life support measures have been instituted.

CLINICAL EFFECTS:

0.2.1 SUMMARY OF EXPOSURE

0.2.1.1 ACUTE EXPOSURE

- A) No human health hazards other than fire and explosion injuries have been reported from industrial hafnium metal exposure. Hafnium salts are irritants of eyes and skin. Experimental animals have sustained liver injury from hafnium exposure.

0.2.4 HEENT

0.2.4.1 ACUTE EXPOSURE

- A) Eye irritation may be seen.

0.2.9 HEPATIC

0.2.9.1 ACUTE EXPOSURE

- A) Mild hepatic injury has been described in experimental animals with chronic exposure.

0.2.14 DERMATOLOGIC

0.2.14.1 ACUTE EXPOSURE

- A) Irritation of unabraded skin occurs with direct contact.

0.2.20 REPRODUCTIVE HAZARDS

- A) At the time of this review, no data were available to assess the potential effects of exposure to this agent during pregnancy or lactation.

0.2.21 CARCINOGENICITY

0.2.21.1 IARC CATEGORY

- A) IARC Carcinogenicity Ratings for CAS7440-58-6 (IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2006; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2007; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2010; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2010a; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2008; IARC, 2004):

1) Not Listed

LABORATORY:

- A) Patients with significant exposure should have liver function tests monitored.

TREATMENT OVERVIEW:

0.4.2 ORAL EXPOSURE

- A) GASTRIC LAVAGE: Consider after ingestion of a potentially life-threatening amount of poison if it can be performed soon after ingestion (generally within 1 hour). Protect airway by placement in the head down left lateral decubitus position or by endotracheal intubation. Control any seizures first.
- 1) CONTRAINDICATIONS: Loss of airway protective reflexes or decreased level of consciousness in unintubated patients; following ingestion of corrosives; hydrocarbons (high aspiration potential); patients at risk of hemorrhage or gastrointestinal perforation; and trivial or non-toxic ingestion.
- B) ACTIVATED CHARCOAL: Administer charcoal as a slurry (240 mL water/30 g charcoal). Usual dose: 25 to 100 g in adults/adolescents, 25 to 50 g in children (1 to 12 years), and 1 g/kg in infants less than 1 year old.

0.4.3 INHALATION EXPOSURE

- A) INHALATION: Move patient to fresh air. Monitor for respiratory distress. If cough or difficulty breathing develops, evaluate for respiratory tract irritation, bronchitis, or pneumonitis. Administer oxygen and assist ventilation as required. Treat bronchospasm with inhaled beta2 agonist and oral or parenteral corticosteroids.
- B) Administer 100% humidified supplemental oxygen with assisted ventilation as required if respiratory tract irritation is present.

0.4.4 EYE EXPOSURE

- A) DECONTAMINATION: Irrigate exposed eyes with copious amounts of room temperature water for at least 15 minutes. If irritation, pain, swelling, lacrimation, or photophobia persist, the patient should be seen in a health care facility.

0.4.5 DERMAL EXPOSURE

A) OVERVIEW

- 1) DECONTAMINATION: Remove contaminated clothing and wash exposed area thoroughly with soap and water. A physician may need to examine the area if irritation or pain persists.

RANGE OF TOXICITY:

- A) The maximum tolerated and minimum lethal human exposures have not been delineated.

ANIMAL TOXICITY STUDIES:

NON-HUMAN TOXICITY EXCERPTS:

/LABORATORY ANIMALS: Subchronic or Prechronic Exposure/ To evaluate the biocompatibility of refractory metals, titanium, hafnium, niobium, tantalum and rhenium were implanted in rats, and histological observation and elemental mapping were performed by X-ray scanning analytical microscope (XSAM) and electron probe microanalyzer (EPMA). The titanium, hafnium, niobium, tantalum and rhenium wires were implanted in the subcutaneous tissue of the abdominal region and in femoral bone marrow of rats for either 2 or 4 weeks. No inflammatory response was observed around the implants, and all the implants were encapsulated with thin fibrous connective tissue. No dissolution of these metals was detected by XSAM in the soft tissue. Histological examination of the hard tissue showed that the amount of new bone formation decreased slightly from the second to the fourth week after implantation, and that the percentage of bone in contact with the implant increased markedly over the same period. No dissolution of these metals was detected by EPMA in the hard tissue. The Ca and P intensities in the mapping images of newly formed bone were higher after 4 weeks than those after 2 weeks, which suggests that the newly formed bone continued to mature from 2 to 4 weeks after implantation. These results indicate that titanium, hafnium, niobium, tantalum and rhenium have good biocompatibility and osteoconductivity.[Matsuno H et al; Biomaterials 22 (11): 1253-62 (2001)] **PEER REVIEWED** PubMed Abstract

/LABORATORY ANIMALS: Subchronic or Prechronic Exposure/ The aim of the present experimental study was to evaluate the tissue response to hafnium (Hf) a reactive metal closely related to titanium (Ti) and zirconium (Zr). Hf has not been previously evaluated as implant material in a biologic environment. In a first experiment, 21 machined Hf non-threaded implants (test) and 21 similar Ti implants (control) were inserted in the abdominal wall of 21 rats. Animals were sacrificed after 8 days (6 rats), 6 (7 rats) and 12 weeks (8 rats). In a second experiment, 18 rabbits received 18 Hf and 18 Ti threaded implants in their tibiae, one implant in each tibia. The rabbits were sacrificed after 6, 12 and 24 weeks (6 animals/time interval). The bulk metal of the abdominal wall implants, embedded together with the surrounding tissue, was electrolytically dissolved and semithin (1 microm) sections of the intact tissue-implant interface were evaluated by light microscopy (morphometry). Bone-implant contact and bone area within threads were evaluated in ground sections. In soft tissues, a fluid space containing predominantly monocytes/macrophages surrounded the abdominal implants at 8 days. At 6 and 12 weeks, a fibrous capsule, consisting of layers of macrophages and fibroblasts, surrounded the implants. Macrophages, including multinuclear giant cells, always formed the innermost layer in contact with the implant surface. No quantitative or qualitative difference in the tissue organization was detected between Ti and Hf implants. In rabbits, 6 weeks after insertion, the proximal two threads located within the cortical bone were filled with bone in contact with Hf and Ti. The distal threads contained bone marrow. After 12 and 24 weeks, mature bone was present in the proximal 3-4 implant threads. No statistically significant difference was found between Hf and Ti implants at any time periods. It is concluded that Hf is an interesting metal for biomedical applications in bone and soft tissue.[Mohammadi S et al; J Mater Sci Mater Med 12 (7): 603-11 (2001)] **PEER REVIEWED** PubMed Abstract

/OTHER TOXICITY INFORMATION/ There have been no published studies on the toxicity of metallic hafnium.[American Conference of Governmental Industrial Hygienists. Documentation of Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 2001. Cincinnati, OH. 2001., p. 1] **PEER REVIEWED**

METABOLISM/PHARMACOKINETICS:

ABSORPTION, DISTRIBUTION & EXCRETION:

Hafnium can be absorbed into the body by inhalation of its aerosol.[Bingham, E.; Cohrssen, B.; Powell, C.H.; Patty's Toxicology Volumes 1-9 5th ed. John Wiley & Sons. New York, N.Y. (2001)., p. V2 p.725] **PEER REVIEWED**

The whole body retention of ¹⁸¹Hf was studied in marmosets (*Callithrix jacchus*) and found to be closely similar to that in rats and Chinese hamsters. Limited tissue distribution studies suggest a higher uptake in liver and much lower deposition in skin and muscle in the marmoset as compared to the rat or Chinese hamster. Studies in Chinese hamsters showed that treatment with the chelating agent diethylenetriaminepentaacetic acid resulted in only a small reduction in the whole body retention of ¹⁸¹Hf. The absorption of orally administered ¹⁸¹Hf, in various chemical forms, was found to be between 0.04 and 0.13% of the ingested dose and was unaffected by age between 5 and 21 months but was increased by fasting. The measured absorption of ¹⁸¹Hf in Chinese hamsters and in rats was similar to that of plutonium suggesting that radiohafnium could be used as a surrogate for plutonium for selected studies in human volunteers. /Radiohafnium/[Taylor DM et al; Int J Nucl Med Biol 12 (5): 387-91 (1985)] **PEER REVIEWED** PubMed Abstract

PHARMACOLOGY:

ENVIRONMENTAL FATE & EXPOSURE:

NATURAL POLLUTION SOURCES:

Hafnium is...never found free in nature. It is always found associated with the more plentiful zirconium.[Kirk-Othmer Encyclopedia of Chemical Technology. 4th ed. Volumes 1: New York, NY. John Wiley and Sons, 1991-Present., p. V12: 863 (1994)] **PEER REVIEWED**

ENVIRONMENTAL STANDARDS & REGULATIONS:

CHEMICAL/PHYSICAL PROPERTIES:

MOLECULAR FORMULA:

Hf **PEER REVIEWED**

MOLECULAR WEIGHT:

178.49[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 81st Edition. CRC Press LLC, Boca Raton: FL 2000, p. 4-62] **PEER REVIEWED**

COLOR/Form:

Gray crystals[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 14th Edition. John Wiley & Sons, Inc. New York, NY 2001., p. 554] **PEER REVIEWED**

Highly lustrous metal of hexagonal crystal structure[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. 13th Edition, Whitehouse Station, NJ: Merck and Co., Inc., 2001., p. 818] **PEER REVIEWED**

Hard, shiny, ductile metal with a color very similar to that of stainless steel ... hafnium sponge metal is a dull powder gray[Kirk-Othmer Encyclopedia of Chemical Technology. 4th ed. Volumes 1: New York, NY. John Wiley and Sons, 1991-Present., p. V12: 863 (1994)] **PEER REVIEWED**

Highly lustrous, ductile, grayish solid.[NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2004-103 (2003).] **PEER REVIEWED**

Crystallizes in a...cubic system which transforms to a hexagonal close-packed system below 2033 K.[Kirk-Othmer Encyclopedia of Chemical Technology. 4th ed. Volumes 1: New York, NY. John Wiley and Sons, 1991-Present., p. V12: 863 (1994)] **PEER REVIEWED**

BOILING POINT:

4603 deg C[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 81st Edition. CRC Press LLC, Boca Raton: FL 2000, p. 4-62] **PEER REVIEWED**

MELTING POINT:

2233 deg C[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 81st Edition. CRC Press LLC, Boca Raton: FL 2000, p. 4-62] **PEER REVIEWED**

CORROSIVITY:

Good corrosion resistance[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 14th Edition. John Wiley & Sons, Inc. New York, NY 2001., p. 554] **PEER REVIEWED**

DENSITY/SPECIFIC GRAVITY:

13.31[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 81st Edition. CRC Press LLC, Boca Raton: FL 2000, p. 4-14] **PEER REVIEWED**

SOLUBILITIES:

Hafnium is slowly attacked by concentrated sulfuric acid. Hafnium is unaffected by nitric acid in all concentrations. It is resistant to dilute solutions of hydrochloric acid and sulfuric acid. Hafnium is attacked by all mineral acids if traces of fluorides are present. Hafnium is very resistant to attack by alkalis.[Kirk-Othmer Encyclopedia of Chemical Technology. 4th ed. Volumes 1: New York, NY. John Wiley and Sons, 1991-Present., p. V12: 863 (1994)] **PEER REVIEWED**

Soluble in hydrogen fluoride[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 81st Edition. CRC Press LLC, Boca Raton: FL 2000, p. 4-62] **PEER REVIEWED**

VAPOR PRESSURE:

1X10-05 Pa at 1767 deg C; 1X10-04 Pa at 2007 deg C[Nielsen RH (2002); Ullman's Encycl Indust Chem 7th ed.(2005). NY, NY: John Wiley & Sons; Hafnium and Hafnium Compounds. Online Posting Date: June 15, 2000.] **PEER REVIEWED**

OTHER CHEMICAL/PHYSICAL PROPERTIES:

Atomic number: 72; ductile; has been successfully alloyed with iron, titanium, niobium, tantalum, and other metals; rapidly absorbs hydrogen to form HfH at 700 deg C; halogens react directly to form tetrahalides; properties are considerably influenced by impurities of zirconium

present[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 81st Edition. CRC Press LLC, Boca Raton: FL 2000, p. 4-14] **PEER REVIEWED**

Standard molar enthalpy of formation (kJ/mol at 298.15 K): 0 (crystal), 619.2 (gas); standard molar Gibbs energy of formation (kJ/mol at 298.15 K): 576.5 (gas); standard molar entropy (J/mol-K at 298.15 K): 43.6 (crystal), 186.9 (gas); molar heat capacity at constant pressure (mol/K at 298.15 K): 25.7 (crystal), 20.8 (gas)[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 81st Edition. CRC Press LLC, Boca Raton: FL 2000, p. 5-19] **PEER REVIEWED**

High thermal neutron cross-section (115 barns); high strength[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 14th Edition. John Wiley & Sons, Inc. New York, NY 2001., p. 554] **PEER REVIEWED**

Zirconium and hafnium chemistries are almost identical ... the density of zirconium is about half that of hafnium.[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 81st Edition. CRC Press LLC, Boca Raton: FL 2000, p. 4-14] **PEER REVIEWED**

Six naturally occurring isotopes: 180 (35.22%); 178 (27.1%); 177 (18.56%); 179 (13.75%); 176 (5.21%); 174 (0.163%; alpha-emitter...); artificial isotopes: 157; 158; 168-173; 175; 181-183.[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. 13th Edition, Whitehouse Station, NJ: Merck and Co., Inc., 2001., p. 818] **PEER REVIEWED**

Finely divided hafnium is pyrophoric and can ignite spontaneously in air...is resistant to concn alkalis[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 81st Edition. CRC Press LLC, Boca Raton: FL 2000, p. 4-14] **PEER REVIEWED**

Enthalpy of fusion: 27.2 kJ/mol at 2233 deg C[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 81st Edition. CRC Press LLC, Boca Raton: FL 2000, p. 6-125] **PEER REVIEWED**

Hafnium's normal stable valence is also its maximum valence of four. Hafnium exhibits coordination numbers of six, seven, and eight in its compounds[Nielsen RH; Kirk-Othmer Encycl Chem Tech (2005). NY, NY: John Wiley & Sons; Hafnium and Hafnium Compounds. Online Posting Date: Jun 18, 2004.] **PEER REVIEWED**

Hafnium is a highly reactive metal. The reaction with air at room temperature is self-limited by the adherent, highly impervious oxide film which is formed...High surface area hafnium powder or porous sponge metal ignites quite easily in air. Clean hafnium metal ignites spontaneously in oxygen of about 2 MPa (300 psi).[Kirk-Othmer Encyclopedia of Chemical Technology. 4th ed. Volumes 1: New York, NY. John Wiley and Sons, 1991-Present., p. V12: 863 (1994)] **PEER REVIEWED**

CHEMICAL SAFETY & HANDLING:

DOT EMERGENCY GUIDELINES:

/GUIDE 135: SUBSTANCES - SPONTANEOUSLY COMBUSTIBLE/ Fire or Explosion: Flammable/combustible material. May ignite on contact with moist air or moisture. May burn rapidly with flare-burning effect. Some react vigorously or explosively on contact with water. Some may decompose explosively when heated or involved in a fire. May re-ignite after fire is extinguished. Runoff may create fire or explosion hazard. Containers may explode when heated. /Hafnium powder, dry/[U.S. Department of

Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 135: SUBSTANCES - SPONTANEOUSLY COMBUSTIBLE/ Health: Fire will produce irritating, corrosive and/or toxic gases. Inhalation of decomposition products may cause severe injury or death. Contact with substance may cause severe burns to skin and eyes. Runoff from fire control may cause pollution. /Hafnium powder, dry/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 135: SUBSTANCES - SPONTANEOUSLY COMBUSTIBLE/ Public Safety: CALL Emergency Response Telephone Number As an immediate precautionary measure, isolate spill or leak area in all directions for at least 50 meters (150 feet) for liquids and at least 25 meters (75 feet) for solids. Stay upwind. Keep unauthorized personnel away. Keep out of low areas. /Hafnium powder, dry/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 135: SUBSTANCES - SPONTANEOUSLY COMBUSTIBLE/ Protective Clothing: Wear positive pressure self-contained breathing apparatus (SCBA). Wear chemical protective clothing that is specifically recommended by the manufacturer. It may provide little or no thermal protection. Structural firefighters' protective clothing will only provide limited protection. /Hafnium powder, dry/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 135: SUBSTANCES - SPONTANEOUSLY COMBUSTIBLE/ Evacuation: ... Fire: If tank, rail car or tank truck is involved in a fire, ISOLATE for 800 meters (1/2 mile) in all directions; also, consider initial evacuation for 800 meters (1/2 mile) in all directions. /Hafnium powder, dry/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 135: SUBSTANCES - SPONTANEOUSLY COMBUSTIBLE/ Fire: DO NOT USE WATER, CO2 OR FOAM ON MATERIAL ITSELF. Some of these materials may react violently with water. ... Small fires: Dry chemical, soda ash, lime or dry sand. ... Large fires: DRY sand, dry chemical, soda ash or lime, ... or withdraw from area and let fire burn. Move containers from fire area if you can do it without risk. Fire involving tanks or car/trailer loads: Fight fire from maximum distance or use unmanned hose holders or monitor nozzles. Do not get water inside containers or in contact with substance. Cool containers with flooding quantities of water until well after fire is out. Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank. ALWAYS stay away from tanks engulfed in fire. /Hafnium powder, dry/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 135: SUBSTANCES - SPONTANEOUSLY COMBUSTIBLE/ Spill or Leak: Fully encapsulating, vapor protective clothing should be worn for spills and leak with no fire. ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area). Do not touch or walk through spilled material. Stop leak if you can do it without risk. Small spills: ... Cover

with DRY earth, DRY sand, or other non-combustible material followed with plastic sheet to minimize spreading or contact with rain. Use clean non-sparking tools to collect material and place it into loosely covered plastic containers for later disposal. Prevent entry into waterways, sewers, basements or confined areas. /Hafnium powder, dry/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 135: SUBSTANCES - SPONTANEOUSLY COMBUSTIBLE/ First Aid: Move victim to fresh air. Call 911 or emergency medical service. Give artificial respiration if victim is not breathing. Administer oxygen if breathing is difficult. Remove and isolate contaminated clothing and shoes. In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes. Keep victim warm and quiet. Ensure that medical personnel are aware of the material(s) involved and take precautions to protect themselves. /Hafnium powder, dry/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 170: METALS (POWDERS, DUSTS, SHAVINGS, BORINGS, TURNINGS, OR CUTTINGS, ETC.)/ Fire or Explosion: May react violently or explosively on contact with water. Some are transported in flammable liquids. May be ignited by friction, heat, sparks or flames. Some of these materials will burn with intense heat. Dusts or fumes may form explosive mixtures in air. Containers may explode when heated. May re-ignite after fire is extinguished. /Hafnium powder, wetted with not less than 25% water/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 170: METALS (POWDERS, DUSTS, SHAVINGS, BORINGS, TURNINGS, OR CUTTINGS, ETC.)/ Health: Oxides from metallic fires are a severe health hazard. Inhalation or contact with substance or decomposition products may cause severe injury or death. Fire may produce irritating, corrosive and/or toxic gases. Runoff from fire control or dilution water may cause pollution. /Hafnium powder, wetted with not less than 25% water/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 170: METALS (POWDERS, DUSTS, SHAVINGS, BORINGS, TURNINGS, OR CUTTINGS, ETC.)/ Public Safety: CALL Emergency Response Telephone Number As an immediate precautionary measure, isolate spill or leak area for at least 50 meters (150 feet) for liquids and at least 25 meters (75 feet) for solids. Stay upwind. Keep unauthorized personnel away. /Hafnium powder, wetted with not less than 25% water/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 170: METALS (POWDERS, DUSTS, SHAVINGS, BORINGS, TURNINGS, OR CUTTINGS, ETC.)/ Protective Clothing: Wear positive pressure self-contained breathing apparatus (SCBA). Structural firefighters' protective clothing will only provide limited protection. /Hafnium powder, wetted with not less than 25% water/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 170: METALS (POWDERS, DUSTS, SHAVINGS, BORINGS, TURNINGS, OR

CUTTINGS, ETC.)/ Evacuation: Large spill: Consider initial downwind evacuation for at least 50 meters (160 feet). Fire: If tank, rail car or tank truck is involved in a fire, ISOLATE for 800 meters (1/2 mile) in all directions; also, consider initial evacuation for 800 meters (1/2 mile) in all directions. /Hafnium powder, wetted with not less than 25% water/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 170: METALS (POWDERS, DUSTS, SHAVINGS, BORINGS, TURNINGS, OR CUTTINGS, ETC.)/ Fire: DO NOT USE WATER, FOAM OR CO2. Dousing metallic fires with water may generate hydrogen gas, an extremely dangerous explosion hazard, particularly if fire is in a confined environment (i.e., building, cargo hold, etc.). Use DRY sand, graphite powder, dry sodium chloride based extinguishers, G-1 or Met-L-X powder. Confining and smothering metal fires is preferable rather than applying water. Move containers from fire area if you can do it without risk. Fire involving tanks or car/trailer loads: If impossible to extinguish, protect surroundings and allow fire to burn itself out. /Hafnium powder, wetted with not less than 25% water/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 170: METALS (POWDERS, DUSTS, SHAVINGS, BORINGS, TURNINGS, OR CUTTINGS, ETC.)/ Spill or Leak: ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area). Do not touch or walk through spilled material. Stop leak if you can do it without risk. Prevent entry into waterways, sewers, basements or confined areas. /Hafnium powder, wetted with not less than 25% water/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

/GUIDE 170: METALS (POWDERS, DUSTS, SHAVINGS, BORINGS, TURNINGS, OR CUTTINGS, ETC.)/ First Aid: Move victim to fresh air. Call 911 or emergency medical service. Give artificial respiration if victim is not breathing. Administer oxygen if breathing is difficult. Remove and isolate contaminated clothing and shoes. In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes. Keep victim warm and quiet. Ensure that medical personnel are aware of the material(s) involved and take precautions to protect themselves. /Hafnium powder, wetted with not less than 25% water/[U.S. Department of Transportation. 2004 Emergency Response Guidebook. A Guide book for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident. Washington, D.C. 2004] **QC REVIEWED**

SKIN, EYE AND RESPIRATORY IRRITATIONS:

Hafnium and its compounds are mild irritants of the eyes, skin, and mucous membranes. No industrial poisonings involving hafnium have been reported.[OSHA; Health Guidelines, NIOSH/OSHA/DOE for Hafnium (7440-58-6). Available from, as of July 13, 2005:

<http://www.osha.gov/SLTC/healthguidelines/hafnium/recognition.html#exposuresources>]

PEER REVIEWED

Irritant /to/ eyes.[Bingham, E.; Cohrssen, B.; Powell, C.H.; Patty's Toxicology Volumes 1-9 5th ed. John Wiley & Sons. New York, N.Y. (2001)., p. V2 p.725] **PEER REVIEWED**

FIRE POTENTIAL:

The substance may spontaneously ignite on contact with air and at higher temperatures with nitrogen, phosphorous and sulphur. /Hafnium powder, wet or dry/[IPCS, CEC; International Chemical Safety Card on Hafnium. (October 1995). Available from, as of June 10, 2005:
<http://www.inchem.org/documents/icsc/icsc/eics0847.htm>] **PEER REVIEWED**

Flammability: Both dry and wet may ignite in powders.[ITII. Toxic and Hazardous Industrial Chemicals Safety Manual. Tokyo, Japan: The International Technical Information Institute, 1988., p. 260] **PEER REVIEWED**

AUTOIGNITION TEMPERATURE:

20 deg C for dust cloud[Sunshine, I. (ed.). CRC Handbook of Analytical Toxicology. Cleveland: The Chemical Rubber Co., 1969., p. 633] **PEER REVIEWED**

FIRE FIGHTING PROCEDURES:

If material on fire or involved in fire: Use suitable dry powder. ... Use dry chemical or carbon dioxide. ... Use water only if flooding quantities are available. /Hafnium powder, dry/[Association of American Railroads/Bureau of Explosives; Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads. Pueblo, CO. 2002., p. 470] **PEER REVIEWED**

If material on fire or involved in fire: Use suitable dry powder. ... Use dry chemical or carbon dioxide. ... Use water only if flooding quantities are available. /Hafnium powder, wetted/[Association of American Railroads/Bureau of Explosives; Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads. Pueblo, CO. 2002., p. 470] **PEER REVIEWED**

TOXIC COMBUSTION PRODUCTS:

Toxic gases and vapors ... may be released in a fire involving hafnium... .[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED**

EXPLOSIVE LIMITS & POTENTIAL:

Explosive in powder form, either dry or wet with less than 25% water.[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 14th Edition. John Wiley & Sons, Inc. New York, NY 2001., p. 554] **PEER REVIEWED**

HAZARDOUS REACTIVITIES & INCOMPATIBILITIES:

Although /hafnium/ is relatively inert, when powdered it becomes very reactive. The dry powder may react explosively at elevated temperatures with nitrogen, phosphorus, oxygen, sulfur and other non-metals. The halogens react similarly, and in contact with hot concentrated nitric acid and other oxidants it may explode (often after a delay with nitric acid). The powder is pyrophoric and readily ignitable by friction, heat or static sparks, and if dry burns fiercely. Presence of water (5-10%) slightly reduces the ease of ignition, but combustion of the damp powder proceeds explosively (the oxygen content of water, 89%, being much higher than that of air).[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 1270] **PEER REVIEWED**

Strong oxidizers, chlorine.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Reacts violently with strong acids, strong oxidants, halogens causing

explosion hazard. /Hafnium powder/[IPCS, CEC; International Chemical Safety Card on Hafnium. (October 1995). Available from, as of June 10, 2005: <http://www.inchem.org/documents/icsc/icsc/eics0847.htm>] **PEER REVIEWED**

HAZARDOUS DECOMPOSITION:

May explosively decompose on shock, friction, or concussion. /Hafnium powder/[IPCS, CEC; International Chemical Safety Card on Hafnium. (October 1995). Available from, as of June 10, 2005: <http://www.inchem.org/documents/icsc/icsc/eics0847.htm>] **PEER REVIEWED**

IMMEDIATELY DANGEROUS TO LIFE OR HEALTH:

Recommended Exposure Limit: 50 mg/cu m (as Hf)[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

PROTECTIVE EQUIPMENT & CLOTHING:

Workmen...should be meticulous in keeping powder off their clothing. If they wear rubber or plastic aprons, these should be treated with an anti-static compound.[International Labour Office. Encyclopedia of Occupational Health and Safety. Volumes I and II. New York: McGraw-Hill Book Co., 1971., p. 1529] **PEER REVIEWED**

Outer clothing made from synthetic fibers should be prohibited unless effectively treated with anti-static materials.[International Labour Office. Encyclopedia of Occupational Health and Safety. Volumes I and II. New York: McGraw-Hill Book Co., 1971., p. 1529] **PEER REVIEWED**

Wear appropriate personal protective clothing to prevent skin contact.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Wear appropriate eye protection to prevent eye contact.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Eyewash fountains should be provided in areas where there is any possibility that workers could be exposed to the substance; this is irrespective of the recommendation involving the wearing of eye protection.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Facilities for quickly drenching the body should be provided within the immediate work area for emergency use where there is a possibility of exposure. [Note: It is intended that these facilities provide a sufficient quantity or flow of water to quickly remove the substance from any body areas likely to be exposed. The actual determination of what constitutes an adequate quick drench facility depends on the specific circumstances. In certain instances, a deluge shower should be readily available, whereas in others, the availability of water from a sink or hose could be considered adequate.][NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Recommendations for respirator selection. Max concn for use: 2.5 mg/cu m. Respirator Class(es): Any dust and mist respirator.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Recommendations for respirator selection. Max concn for use: 5 mg/cu m.
Respirator Class(es): Any dust and mist respirator except single-use and quarter-mask respirators. Any supplied-air respirator.[NIO SH. NIO SH Pocket Guide to Chemical Hazards. DHHS (NIO SH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Recommendations for respirator selection. Max concn for use: 12.5 mg/cu m.
Respirator Class(es): Any supplied-air respirator operated in a continuous flow mode. May require eye protection. Any powered, air-purifying respirator with a dust and mist filter. May require eye protection.[NIO SH. NIO SH Pocket Guide to Chemical Hazards. DHHS (NIO SH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Recommendations for respirator selection. Max concn for use: 25 mg/cu m.
Respirator Class(es): Any air-purifying, full-facepiece respirator with a high-efficiency particulate filter. Any supplied-air respirator that has a tight-fitting facepiece and is operated in a continuous-flow mode. May require eye protection. Any powered, air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate filter. May require eye protection. Any self-contained breathing apparatus with a full facepiece. Any supplied-air respirator with a full facepiece.[NIO SH. NIO SH Pocket Guide to Chemical Hazards. DHHS (NIO SH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Recommendations for respirator selection. Max concn for use: 50 mg/cu m.
Respirator Class(es): Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode.[NIO SH. NIO SH Pocket Guide to Chemical Hazards. DHHS (NIO SH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Recommendations for respirator selection. Condition: Emergency or planned entry into unknown concn or IDLH conditions: Respirator Class(es): Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive pressure mode. Any supplied-air respirator with a full facepiece and operated in pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.[NIO SH. NIO SH Pocket Guide to Chemical Hazards. DHHS (NIO SH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Recommendations for respirator selection. Condition: Escape from suddenly occurring respiratory hazards: Respirator Class(es): Any air-purifying, full-facepiece respirator with a high-efficiency particulate filter. Any appropriate escape-type, self-contained breathing apparatus.[NIO SH. NIO SH Pocket Guide to Chemical Hazards. DHHS (NIO SH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

... Clothing should be flame-resistant and should be treated or should be of a type so as to minimize the static electricity hazard of ignition.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIO SH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIO SH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED**

Personnel protection: Wear appropriate chemical protective gloves, boots,

and goggles. /Hafnium powder, dry/[Association of American Railroads/Bureau of Explosives; Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads. Pueblo, CO. 2002., p. 470] **PEER REVIEWED**

Personnel protection: Wear appropriate chemical protective gloves, boots, and goggles. /Hafnium powder, wetted/[Association of American Railroads/Bureau of Explosives; Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads. Pueblo, CO. 2002., p. 470] **PEER REVIEWED**

PREVENTIVE MEASURES:

Ventilation control: ...all processes using these materials /zirconium and hafnium/ should be...ventilated to keep air-borne contaminants far below.../5 mg/cu m/[International Labour Office. Encyclopedia of Occupational Health and Safety. Volumes I and II. New York: McGraw-Hill Book Co., 1971., p. 1529] **PEER REVIEWED**

Care should be taken when machining metal or when handling hot sponge hafnium.[Weast, R.C. (ed.). Handbook of Chemistry and Physics. 60th ed. Boca Raton, Florida: CRC Press Inc., 1979., p. B-11] **PEER REVIEWED**

All sources of ignition, including static electric charges, should be eliminated from areas in which powder is to be handled. All surfaces...should be impervious and seamless so that they can be washed down with water and kept completely free from dust. Dried powders should be disturbed and handled as little as possible and then only with non-sparking tools.[International Labour Office. Encyclopedia of Occupational Health and Safety. Volumes I and II. New York: McGraw-Hill Book Co., 1971., p. 1529] **PEER REVIEWED**

The worker should immediately wash the skin when it becomes contaminated.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

The worker should wash daily at the end of each work shift.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Work clothing that becomes wet or significantly contaminated should be removed and replaced.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Workers whose clothing may have become contaminated should change into uncontaminated clothing before leaving the work premises.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

Clothing which has had any possibility of being contaminated with wet or dry hafnium powder should be placed in fireproof closed containers for storage until it can be discarded or until provision is made for the removal of hafnium from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the hafnium, the person performing the operation should be informed of hafnium's hazardous properties.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED**

SRP: Contaminated protective clothing should be segregated in such a manner so that there is no direct personal contact by personnel who handle, dispose, or clean the clothing. Quality assurance to ascertain the completeness of the cleaning procedures should be implemented before the decontaminated protective clothing is returned for reuse by the workers. Contaminated clothing should not be taken home at end of shift, but should remain at employee's place of work for cleaning. **PEER REVIEWED**

Do not eat, drink, or smoke during work. Always wash hands before eating.[Bingham, E.; Cohrssen, B.; Powell, C.H.; Patty's Toxicology Volumes 1-9 5th ed. John Wiley & Sons. New York, N.Y. (2001)., p. V2 p.725] **PEER REVIEWED**

If material not on fire and not involved in fire: Keep sparks, flames and other sources of ignition away. ... Keep material out of water sources and sewers. /Hafnium powder, dry/[Association of American Railroads/Bureau of Explosives; Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads. Pueblo, CO. 2002., p. 470] **PEER REVIEWED**

If material not on fire and not involved in fire: Keep sparks, flames and other sources of ignition away. ... Keep material out of water sources and sewers. /Hafnium powder, wetted/[Association of American Railroads/Bureau of Explosives; Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads. Pueblo, CO. 2002., p. 470] **PEER REVIEWED**

Personnel protection: Avoid breathing dusts, and fumes from burning material. ... Do not handle broken packages unless wearing appropriate personal protective equipment. ... Wash away any material which may have contacted the body with copious amounts of water or soap and water. /Hafnium powder, wetted/[Association of American Railroads/Bureau of Explosives; Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads. Pueblo, CO. 2002., p. 470] **PEER REVIEWED**

Personnel protection: Avoid breathing dusts, and fumes from burning material. ... Do not handle broken packages unless wearing appropriate personal protective equipment. ... Wash away any material which may have contacted the body with copious amounts of water or soap and water. /Hafnium powder, dry/[Association of American Railroads/Bureau of Explosives; Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads. Pueblo, CO. 2002., p. 470] **PEER REVIEWED**

SRP: The scientific literature for the use of contact lenses in industry is conflicting. The benefit or detrimental effects of wearing contact lenses depend not only upon the substance, but also on factors including the form of the substance, characteristics and duration of the exposure, the uses of other eye protection equipment, and the hygiene of the lenses. However, there may be individual substances whose irritating or corrosive properties are such that the wearing of contact lenses would be harmful to the eye. In those specific cases, contact lenses should not be worn. In any event, the usual eye protection equipment should be worn even when contact lenses are in place. **PEER REVIEWED**

SRP: Local exhaust ventilation should be applied wherever there is an incidence of point source emissions or dispersion of regulated contaminants in the work area. Ventilation control of the contaminant as close to its point of generation is both the most economical and safest method to minimize personnel exposure to airborne contaminants. **PEER

REVIEWED**

SHIPMENT METHODS AND REGULATIONS:

No person may /transport,/ offer or accept a hazardous material for transportation in commerce unless that person is registered in conformance ... and the hazardous material is properly classed, described, packaged, marked, labeled, and in condition for shipment as required or authorized by ... /the hazardous materials regulations (49 CFR 171-177)./[49 CFR 171.2; U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of February 5, 2004: <http://www.gpoaccess.gov/ecfr/>] **PEER REVIEWED**

The International Air Transport Association (IATA) Dangerous Goods Regulations are published by the IATA Dangerous Goods Board pursuant to IATA Resolutions 618 and 619 and constitute a manual of industry carrier regulations to be followed by all IATA Member airlines when transporting hazardous materials.[IATA. Dangerous Goods Regulations. 45 th Ed. Montreal, Canada and Geneva, Switzerland. International Air Transport Association. Dangerous Goods Regulations, 2004., p. 177] **PEER REVIEWED**

The International Maritime Dangerous Goods Code lays down basic principles for transporting hazardous chemicals. Detailed recommendations for individual substances and a number of recommendations for good practice are included in the classes dealing with such substances. A general index of technical names has also been compiled. This index should always be consulted when attempting to locate the appropriate procedures to be used when shipping any substance or article.[IMDG; International Maritime Dangerous Goods Code; International Maritime Organization p.4237,4148 (1998)] **PEER REVIEWED**

STORAGE CONDITIONS:

Storage: Store hafnium in a fireproof area. Keep it separate from strong oxidizing agents, strong bases, halogens, phosphorus, and sulfur. Keep stored under water.[Bingham, E.; Cohrssen, B.; Powell, C.H.; Patty's Toxicology Volumes 1-9 5th ed. John Wiley & Sons. New York, N.Y. (2001)., p. V2 p.725] **PEER REVIEWED**

CLEANUP METHODS:

Persons not wearing protective equipment and clothing should be restricted from areas of spills until cleanup has been completed. 1. Ventilate area of spill. 2. Collect spilled material in most convenient and safe manner and deposit in sealed containers for reclamation, or for disposal in secured sanitary landfill. Liq containing hafnium...should be absorbed in vermiculite, dry sand, earth, or similar material.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED**

Any spilled powder should be cleaned up immediately with water so that it has no chance to dry in place.[International Labour Office. Encyclopedia of Occupational Health and Safety. Volumes I and II. New York: McGraw-Hill Book Co., 1971., p. 1529] **PEER REVIEWED**

Spillage disposal: Evacuate danger area. Eliminate all sources of ignition. Do not wash away into sewer because it is flammable. Do not absorb in sawdust or other combustible absorbents. Wet the powder to prevent formation of dust or ignition; carefully collect the powder into sealable containers, and remove it to a safe place. During this procedure, use extra personal protection, e.g., a P2 filter respirator for harmful particles.[Bingham, E.; Cohrssen, B.; Powell, C.H.; Patty's Toxicology Volumes 1-9 5th ed. John Wiley & Sons. New York, N.Y. (2001)., p. V2

p.725] **PEER REVIEWED**

Environmental considerations: land spill: Dig a pit, pond, lagoon, holding area to contain liquid or solid material. ... Apply appropriate foam to diminish vapor and fire hazard. ... /SRP: If time permits, pits, ponds, lagoons, soak holes, or holding areas should be sealed with an impermeable flexible membrane liner./ /Hafnium powder, wetted/[Association of American Railroads/Bureau of Explosives; Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads. Pueblo, CO. 2002., p. 470] **PEER REVIEWED**

Environmental considerations: water spill: Use natural barriers or oil spill control booms to limit spill travel. /Hafnium powder, wetted/[Association of American Railroads/Bureau of Explosives; Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads. Pueblo, CO. 2002., p. 470] **PEER REVIEWED**

DISPOSAL METHODS:

SRP: The most favorable course of action is to use an alternative chemical product with less inherent propensity for occupational exposure or environmental contamination. Recycle any unused portion of the material for its approved use or return it to the manufacturer or supplier. Ultimate disposal of the chemical must consider: the material's impact on air quality; potential migration in soil or water; effects on animal, aquatic, and plant life; and conformance with environmental and public health regulations. **PEER REVIEWED**

If the quantity justifies recovery, get in touch with the supplier for special instructions.[ITII. Toxic and Hazardous Industrial Chemicals Safety Manual. Tokyo, Japan: The International Technical Information Institute, 1988., p. 260] **PEER REVIEWED**

Used papers and cloths which have become contaminated with powders should be kept wet in covered Containers until they are /disposed/. [International Labour Office. Encyclopedia of Occupational Health and Safety. Volumes I and II. New York: McGraw-Hill Book Co., 1971., p. 1529] **PEER REVIEWED**

OCCUPATIONAL EXPOSURE STANDARDS:

OSHA STANDARDS:

Permissible Exposure Limit: Table Z-1 8-hr Time Weighted Avg: 0.5 mg/cu m.[29 CFR 1910.1000 (7/1/98)] **PEER REVIEWED**

THRESHOLD LIMIT VALUES:

8 hr Time Weighted Avg (TWA): 0.5 mg/cu m. /Hafnium and compounds, as Hf/[American Conference of Governmental Industrial Hygienists TLVs and BEIs. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati, OH, 2008, p. 32] **QC REVIEWED**

Excursion Limit Recommendation: Excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a work day, and under no circumstances should they exceed 5 times the TLV-TWA, provided that the TLV-TWA is not exceeded. /Hafnium and compounds, as Hf/[American Conference of Governmental Industrial Hygienists TLVs and BEIs. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati, OH, 2008, p. 5] **QC REVIEWED**

NIOSH RECOMMENDATIONS:

Recommended Exposure Limit: 10 Hr Time-Weighted Avg: 0.5 mg/cu m.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

IMMEDIATELY DANGEROUS TO LIFE OR HEALTH:

Recommended Exposure Limit: 50 mg/cu m (as Hf)[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 156] **PEER REVIEWED**

MANUFACTURING/USE INFORMATION:

MAJOR USES:

Use in control rods in water-cooled nuclear reactors; in gas-filled tubes and incandescent lamps as a scavenger for oxygen and nitrogen; in the manufacture of photographic flash bulbs, light bulb filaments, and in electronic equipment as cathodes and capacitors.[OSHA; Health Guidelines, NIOSH/OSHA/DOE for Hafnium (7440-58-6). Available from, as of July 13, 2005:

<http://www.osha.gov/SLTC/healthguidelines/hafnium/recognition.html#exposuresources>]

PEER REVIEWED

Use as a substitute for tantalum in cemented carbide tool bits, as a coating on rocket engine parts, and in radio and television tubes, and in X-ray tubes[OSHA; Health Guidelines, NIOSH/OSHA/DOE for Hafnium (7440-58-6). Available from, as of July 13, 2005:

<http://www.osha.gov/SLTC/healthguidelines/hafnium/recognition.html#exposuresources>]

PEER REVIEWED

Cemented carbide cutting tools[Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. V12 73] **PEER REVIEWED**

The major uses of hafnium involve the metal. The largest use is as an alloying additive (1 - 2%) in nickel-based superalloys. These alloys are used in turbine vanes in the combustion zone of jet aircraft engines.[Nielsen RH; Hafnium and Hafnium Compounds. (2002) in Ullmann's Encycl Indust Chem. 7th ed. (2005). NY, NY: John Wiley & Sons. Online Posting Date: June 15, 2000.] **PEER REVIEWED**

The leading market for hafnium metal is as a addition in superalloys.[USGS; Mineral Commodity Summaries, Zirconium and Hafnium (2005). Available from, as of June 1, 2005:
<http://minerals.usgs.gov/minerals/pubs/mcs/>] **PEER REVIEWED**

MANUFACTURERS:

ATI Wah Chang, P.O. Box 460, Albany, OR 97321, (888) 926-4211; Production site: Albany, OR 97321 /Hafnium metal powder/[SRI Consulting. 2005 Directory of Chemical Producers - United States, Menlo Park, CA. 2005, p. 43] **PEER REVIEWED**

Cerac, Inc., P.O. Box 1178, Milwaukee, WI 53201-1178, (414) 289-9800; Production site: Milwaukee, WI 53233 /Hafnium compounds/[SRI Consulting. 2005 Directory of Chemical Producers - United States, Menlo Park, CA. 2005, p. 43] **PEER REVIEWED**

Hafnium metal was produced from zircon sand by two domestic producers, one in Oregon and the other in Utah. Typically both /zirconium and hafnium/ metals are in the ore in a zirconium to hafnium ratio of 50:1[USGS; Mineral Commodity Summaries. Zirconium and Hafnium. Available from, as of Jul 12, 2005: <http://minerals.usgs.gov/minerals/pubs/commodity/>] **PEER REVIEWED**

METHODS OF MANUFACTURING:

Extraction from the mineral cryolite.[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. 13th Edition, Whitehouse Station, NJ: Merck and Co., Inc., 2001., p. 818] **PEER REVIEWED**

Prepared by thermal decomposition of its iodide; by reduction of tetrachloride or of hydrofluohafniate with metallic sodium; by reduction of oxide with a mixture of calcium and sodium.[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. 13th Edition, Whitehouse Station, NJ: Merck and Co., Inc., 2001., p. 818] **PEER REVIEWED**

Extremely difficult to separate from zirconium. Most important methods are: 1) solvent extraction of thiocyanates by hexone; 2) solvent extraction of nitrates by tributyl phosphate; 3) fractional crystallization of double fluorides.[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 14th Edition. John Wiley & Sons, Inc. New York, NY 2001., p. 554] **PEER REVIEWED**

It was originally separated from zirconium by repeated recrystallization of the double ammonium or potassium fluorides by von Hevesey and Jantezen. Metallic hafnium was first prepared by van Arkel and deBoer by passing the vapor of the tetraiodide over heated a tungsten filament. Almost all hafnium metal now produced is made by reducing the tetrachloride with magnesium or with sodium (Kroll Process).[Lide, D.R. (ed.). CRC Handbook of Chemistry and Physics. 83rd ed. Boca Raton, FL: CRC Press Inc., 2002-2003., p. 4-14] **PEER REVIEWED**

US 2741628[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. 13th Edition, Whitehouse Station, NJ: Merck and Co., Inc., 2001., p. 818] **PEER REVIEWED**

GENERAL MANUFACTURING INFORMATION:

Price of the metal is about \$2/g.[Lide, D.R. (ed.). CRC Handbook of Chemistry and Physics. 83rd ed. Boca Raton, FL: CRC Press Inc., 2002-2003., p. 4-14] **PEER REVIEWED**

...Extensively used as shielding material & as control rods in thermal nuclear reactors, because its thermal neutron cross section, 105 barns, is nearly 1000 times that of Zr; Hf can absorb & give up heat twice as fast as Zr & Ti. It is used as construction material in space technology & in jet engines...[Venugopal, B. and T.D. Luckey. Metal Toxicity in Mammals, 2. New York: Plenum Press, 1978., p. 203] **PEER REVIEWED**

Although hafnium /ore/ reserves are significant, demand is low and easily met as a byproduct of the production of reactor-grade zirconium[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed. Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA12 560] **PEER REVIEWED**

Six naturally occurring isotopes: 180 (35.22%); 178 (27.1%); 177 (18.56%); 179 (13.75%); 176 (5.21%); 174 (0.163%; alpha-emitter...); artificial isotopes: 157; 158; 168-173; 175; 181-183.[O'Neil, M.J. (ed.). The Merck

Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. 13th Edition, Whitehouse Station, NJ: Merck and Co., Inc., 2001., p. 818]
PEER REVIEWED

FORMULATIONS/PREPARATIONS:

Forms available: powder; rods; single crystals[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 14th Edition. John Wiley & Sons, Inc. New York, NY 2001., p. 554] **PEER REVIEWED**

Available in sponge, iodide crystal bar, ingot, wrought products from bar to foil, and wire[Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. V12 72] **PEER REVIEWED**

Sold in chunk or particulate form /for alloying purposes/[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA12 564] **PEER REVIEWED**

IMPURITIES:

Of all elements, zirconium and hafnium are two of most difficult to separate. ... Very pure hafnium has been produced with zirconium being the major impurity.[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 71st ed. Boca Raton, FL: CRC Press Inc., 1990-1991., p. 4-15] **PEER REVIEWED**

CONSUMPTION PATTERNS:

The largest use is as an alloy additive in nickel-based superalloys ... second major use is as a control-rod material in nuclear reactors[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA12: 564] **PEER REVIEWED**

YEARLY DEMAND FOR HAFNIUM IN US IS NOW IN EXCESS OF 60,000 LB.[Weast, R.C. (ed.). Handbook of Chemistry and Physics. 60th ed. Boca Raton, Florida: CRC Press Inc., 1979., p. B-11] **PEER REVIEWED**

The yearly demand for hafnium in the US is now /1990/ in excess of 100,000 lb[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 71st ed. Boca Raton, FL: CRC Press Inc., 1990-1991., p. 4-15] **PEER REVIEWED**

Yearly demand for hafnium in US is now /2002/ in excess of 50,000 kg.[Lide, DR (ed.). CRC Handbook of Chemistry and Physics. 81st Edition. CRC Press LLC, Boca Raton: FL 2000, p. 4-14] **PEER REVIEWED**

U. S. IMPORTS:

2 metric tons (1992; hafnium, unwrought and waste and scrap)[Bureau of Mines; 1992 Minerals Yearbook, Annual Report, US Dept Interior, p. 1494]
PEER REVIEWED

(2000) 11 metric tons /Hafnium, unwrought, waste and scrap/[USGS; Mineral Commodity Summaries, Zirconium and Hafnium (2005). Available from, as of June 1, 2005: <http://minerals.usgs.gov/minerals/pubs/mcs/>] **PEER REVIEWED**

(2001) 5 metric tons /Hafnium, unwrought, waste and scrap/[USGS; Mineral Commodity Summaries, Zirconium and Hafnium (2005). Available from, as of June 1, 2005: <http://minerals.usgs.gov/minerals/pubs/mcs/>] **PEER REVIEWED**

(2002) 5 metric tons /Hafnium, unwrought, waste and scrap/[USGS; Mineral Commodity Summaries, Zirconium and Hafnium (2005). Available from, as of

June 1, 2005: <http://minerals.usgs.gov/minerals/pubs/mcs/>] **PEER REVIEWED**

(2003) 5 metric tons /Hafnium, unwrought, waste and scrap/[USGS; Mineral Commodity Summaries, Zirconium and Hafnium (2005). Available from, as of June 1, 2005: <http://minerals.usgs.gov/minerals/pubs/mcs/>] **PEER REVIEWED**

(2004) 3 metric tons, estimated /Hafnium, unwrought, waste and scrap/[USGS; Mineral Commodity Summaries, Zirconium and Hafnium (2005). Available from, as of June 1, 2005: <http://minerals.usgs.gov/minerals/pubs/mcs/>] **PEER REVIEWED**

LABORATORY METHODS:

SPECIAL REFERENCES:

SPECIAL REPORTS:

USEPA; Development Document for Effluent Limitations, Guidelines, & Standards for the Nonferrous Metals Manufacturing Point Source Category. Vol 9 Primary & Secondary Titanium, Primary Zirconium & Hafnium; GRA & I Issue 11 (1990) EPA 440/1-89/019.9

SYNONYMS AND IDENTIFIERS:

RELATED HSDB RECORDS:

7345 [HAFNIUM COMPOUNDS]

SYNONYMS:

CELTIIUM **PEER REVIEWED**

HAFNIUM METAL, DRY (DOT)[U.S. Department of Health and Human Services, Public Health Service, Center for Disease Control, National Institute for Occupational Safety Health. Registry of Toxic Effects of Chemical Substances (RTECS). National Library of Medicine's current MEDLARS file., p. 82/8201] **PEER REVIEWED**

HAFNIUM METAL, WET (DOT)[U.S. Department of Health and Human Services, Public Health Service, Center for Disease Control, National Institute for Occupational Safety Health. Registry of Toxic Effects of Chemical Substances (RTECS). National Library of Medicine's current MEDLARS file., p. 82/7901] **PEER REVIEWED**

FORMULATIONS/PREPARATIONS:

Forms available: powder; rods; single crystals[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 14th Edition. John Wiley & Sons, Inc. New York, NY 2001., p. 554] **PEER REVIEWED**

Available in sponge, iodide crystal bar, ingot, wrought products from bar to foil, and wire[Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. V12 72] **PEER REVIEWED**

Sold in chunk or particulate form /for alloying purposes/[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA12 564] **PEER

REVIEWED**

SHIPPING NAME/ NUMBER DOT/UN/NA/IMO:

UN 4237; Hafnium powder, dry

UN 2545; Hafnium powder, dry

UN 1326; Hafnium powder, wetted with not less than 25% water

IMO 4.2; Hafnium powder, dry

IMO 4.1; Hafnium powder, wetted with not less than 25% water

STANDARD TRANSPORTATION NUMBER:

49 167 12; Hafnium metal, wet

49 167 11; Hafnium metal, dry

ADMINISTRATIVE INFORMATION:

HAZARDOUS SUBSTANCES DATABANK NUMBER: 552

LAST REVISION DATE: 20060414

LAST REVIEW DATE: Reviewed by SRP on 9/15/2005

UPDATE HISTORY:

Field Update on 2009-04-16, 2 fields added/edited/deleted

Field Update on 2008-08-15, 25 fields added/edited/deleted

Field Update on 2007-02-26, 1 fields added/edited/deleted

Complete Update on 2006-04-14, 41 fields added/edited/deleted

Complete Update on 2005-06-24, 19 fields added/edited/deleted

Field Update on 2005-01-29, 2 fields added/edited/deleted

Complete Update on 10/16/2002, 1 field added/edited/deleted.

Complete Update on 07/22/2002, 1 field added/edited/deleted.

Complete Update on 01/14/2002, 1 field added/edited/deleted.

Complete Update on 08/09/2001, 1 field added/edited/deleted.

Complete Update on 02/08/2000, 1 field added/edited/deleted.

Complete Update on 02/02/2000, 1 field added/edited/deleted.

Complete Update on 11/18/1999, 1 field added/edited/deleted.

Complete Update on 09/21/1999, 1 field added/edited/deleted.

Complete Update on 07/27/1999, 5 fields added/edited/deleted.

Complete Update on 01/27/1999, 1 field added/edited/deleted.

Complete Update on 11/12/1998, 2 fields added/edited/deleted.

Complete Update on 06/02/1998, 1 field added/edited/deleted.
Complete Update on 04/01/1997, 2 fields added/edited/deleted.
Complete Update on 05/17/1996, 1 field added/edited/deleted.
Complete Update on 05/10/1996, 1 field added/edited/deleted.
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Complete Update on 01/12/1995, 40 fields added/edited/deleted.
Field Update on 12/21/1994, 1 field added/edited/deleted.
Complete Update on 03/25/1994, 1 field added/edited/deleted.
Complete Update on 08/07/1993, 1 field added/edited/deleted.
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Complete Update on 12/09/1988, 2 fields added/edited/deleted.
Complete Update on 07/12/1988, 2 fields added/edited/deleted.
Complete Update on 02/26/1988, 3 fields added/edited/deleted.

Complete Update on 06/04/1985

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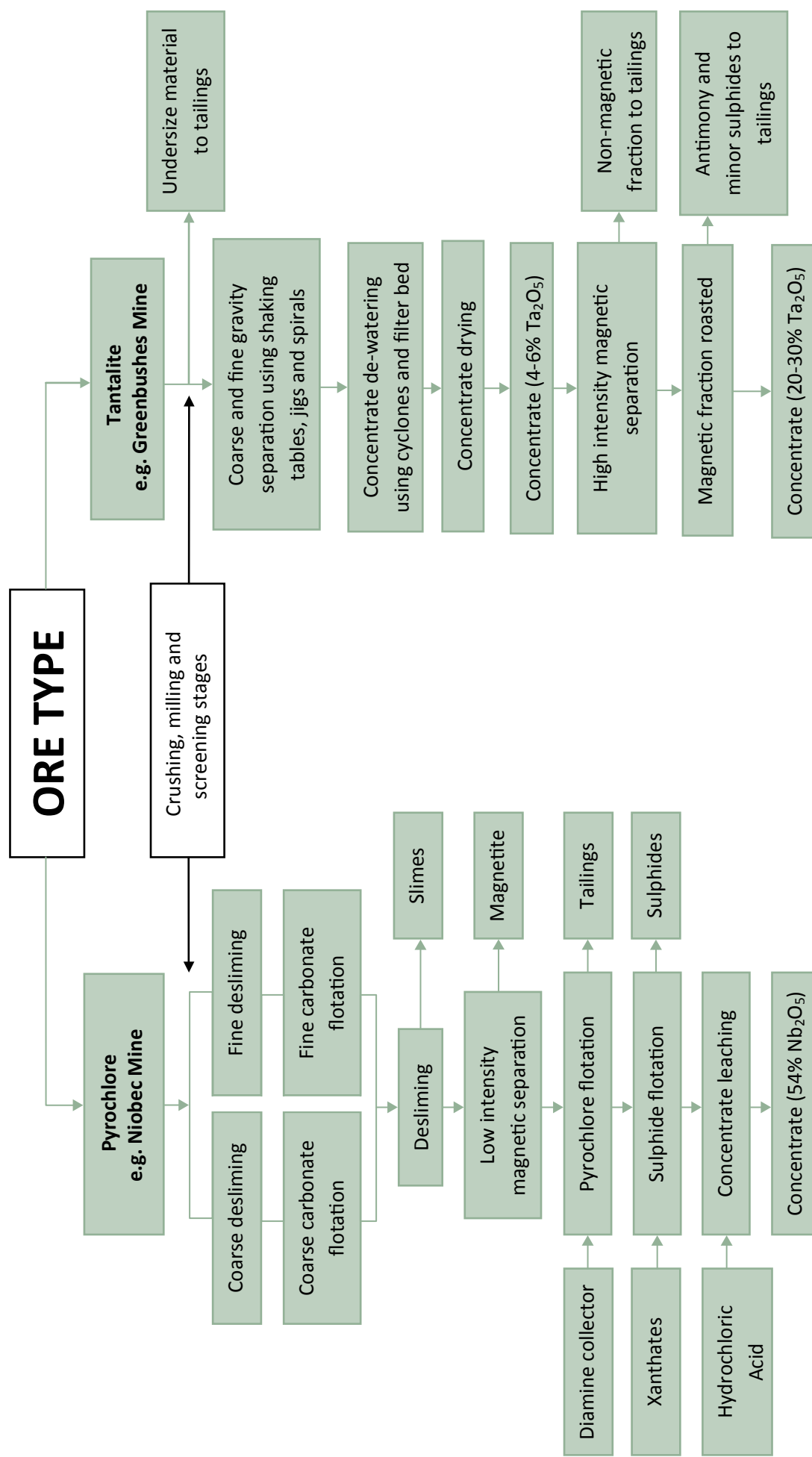


Figure 4 Generalised beneficiation flow diagrams, based upon the Niobec and Greenbushes operations.

Niobium–tantalum

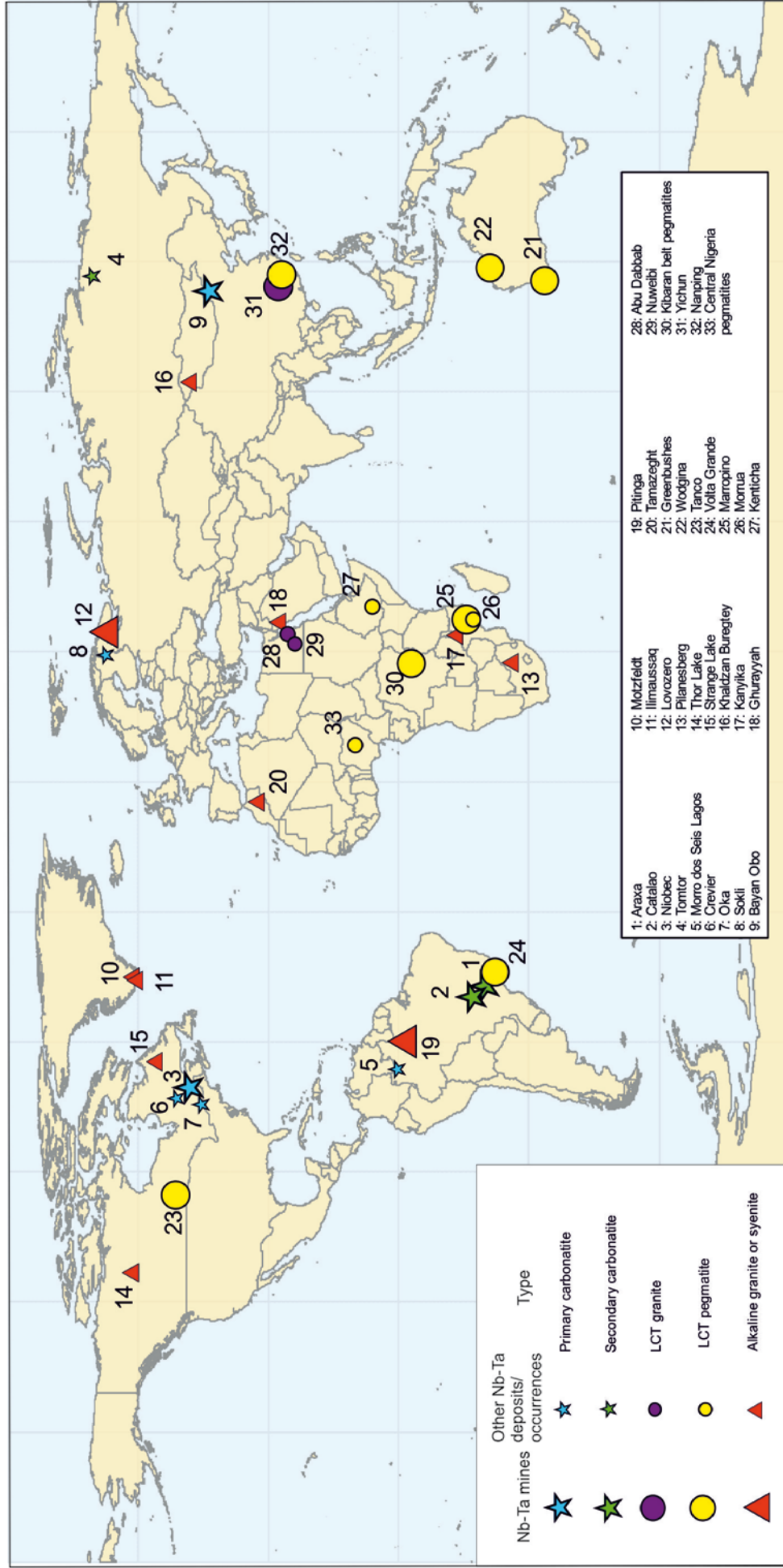


Figure 3 Map showing the global distribution of niobium and tantalum mines, deposits and major occurrences.