

Chapter 1 : Why You Generally Shouldn't Put Metals in the Microwave

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All radioactive particles and waves, from the entire electromagnetic spectrum, to alpha, beta, and gamma particles, possess the ability to eject electrons from atoms and molecules to create ions. Introduction There are many types of radiation, but the two most common are electromagnetic radiation and ionizing radiation. Unlike ionizing radiation, electromagnetic radiation deals with electric and magnetic field oscillations such as with X-rays, radio waves, or gamma rays. Radioactive decay of atoms creates three radioactive particles, alpha, beta, and gamma. However, a common misconception is that the higher ionizing power a particle has, the more damaging it is to matter. Electromagnetic waves can also ionize, hence the reason electromagnetic radiation is often placed as part of ionizing radiation. Primary Electrons and Secondary Ionization The main effect radiation has on matter is its ability to ionize atoms to become ions, a phenomenon known as ionization, which is very similar to the photoelectric effect. Radioactive particles or electromagnetic waves with sufficient energy collide with electrons on the atom to knock electrons off the atom. The electron ejected off the atom is called the primary electron. When the primary electrons hold energy, a particle ejecting the primary electron may cause it to eject another electron, either on their own atom or on another atom. This is known as secondary ionization. However, ionization does not have to completely eject an electron off the atom. It can raise the energy of the electron instead, raising the electron energy to a higher energy state. When the electron reverts to its normal energy level, it emits energy in the form of radiation, usually in the forms of ultraviolet rays or radio waves. Artificially induced radioactivity utilizes primary and secondary ionizations in order to emit X-rays. Most X-ray emission is due to the bombardment of electrons on a metal target. If the electrons have sufficient energy, the inner shell electrons of the atom fall out, and higher-levelled electrons fill in the hole left by the previous electrons. By doing so, packets of energy are released in the forms of X-ray photons. Other forms of ionizing radiation can produce UV and gamma rays in a similar manner. Radio waves, microwaves, and neutron radiation an important application in fission and fusion all fall under non-ionizing radiation, as their respective energies are too low to ionize atoms. How far they penetrate is dependent on the different types of radiation and their ionizing power. Since alpha particles are high in ionizing power, it is difficult for them to penetrate matter thoroughly. This is because alpha particles are likely to ionize the first thing they come into contact with; thus, they hold a small range of penetrating power. The inverse relation between ionizing power and penetrating power can be applied to beta and gamma rays as well. Alpha particles can be stopped with a sheet of paper or a layer of clothing, while beta particles can penetrate up to a fraction of an inch in solids and liquids and several feet in air. Gamma rays, which are electrically neutral and have small ionizing power, are not slowed by collisions with materials and can only be stopped with heavy metals such as lead. Effects of Radiation on Living Matter Prolonged exposure to radiation often has detrimental effects on living matter. Radiation either ionizes or excites atoms or molecules in living cells, leading to the dissociation of molecules within an organism. The most destructive effect radiation has on living matter is ionizing radiation on DNA. Effects from exposure to radiation include leukemia, birth defects, and many forms of cancer. Most external radiation is absorbed by the environment; for example, most ultraviolet radiation is absorbed by the ozone layer, preventing deadly levels of ultraviolet radiation to come in contact with the surface of the earth. Sunburn is an effect of UV radiation damaging skin cells, and prolonged exposure to UV radiation can cause genetic information in skin cells to mutate, leading to skin cancer. Alpha, beta, and gamma rays also cause damage to living matter, in varying degrees. Alpha particles have a very small absorption range, and thus are usually not harmful to life, unless ingested, due to its high ionizing power. Beta particles are also damaging to DNA, and therefore are often used in radiation therapy to mutate and kill cancer cells. Gamma rays are often considered the most dangerous type of radiation to living matter. Unlike alpha and beta particles, which are charged particles, gamma rays are instead forms of energy. They have large penetrating range and can diffuse through many cells before dissipating, causing widespread damage such as radiation sickness. Because gamma rays have such high penetrating power and can damage

living cells to a great extent, they are often used in irradiation, a process used to kill living organisms. Radiation Dosage and Decay There are several methods to measure radiation; hence, there are several radiation units based on different radiation factors. Radiation units can measure radioactive decay, absorbed dosage, and human absorbed doses. Bq and Ci measure radioactive decay, while Gy and Rad measures absorbed doses. Sv and Rem measure absorbed doses in Gy and Rad equivalents. Rem takes into account different radiation types and the speed of particles. Below is a chart to help organize the different units:

Chapter 2 : Naturally Occurring Radioactive Materials NORM - World Nuclear Association

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Annual consumption in WOCA 7. However, the platinum group metals content of the fission product of spent fuel is not immediately available to man. For the metals to become attainable it is necessary for the fuel to be reprocessed. It is thought likely that about half the nuclear fuel from power reactors worldwide will be reprocessed 2. Behaviour of Platinum Group Metals during Fuel Processing When spent nuclear fuel is reprocessed, the fuel pins are sheared into short lengths, and the fuel is dissolved away from the cladding into 7M nitric acid. During this operation, the uranium and plutonium oxides that are present dissolve, as do most of the fission products. There is, however, an insoluble residue which contains some of the platinum group metals. The acid solution is clarified and then passes to a sequence of solvent extraction contactors in which separation of uranium and plutonium from the fission products, and from each other, is carried out. Most of the fission products in the dissolver solution, including the platinum group metals, pass to the aqueous raffinate from the first solvent extraction cycle. This raffinate is subsequently concentrated by evaporation to give high level waste liquor, which is then stored prior to vitrification and final disposal. During these stages further precipitation of insoluble material can occur. Insoluble Residues The insoluble material from the dissolution stage contains 70 to 90 per cent fission products, together with miscellaneous residues and traces of undissolved actinides. These fission products exist as metallic alloys containing molybdenum and technetium as well as palladium, rhodium and ruthenium. The fraction of the initial inventory of platinum group metals which occurs in the insoluble residues depends on the burn-up to which the fuel has been taken. For high burn-up fast reactor fuel, about 98 per cent of the total expected ruthenium has been found in the residues 3. The insoluble residues are difficult to treat chemically because of their inertness, and their high radioactivity adds to the difficulty and expense of processing them. Direct high temperature chlorination, or alloying with tin, has been used to bring the residues into solution for analytical purposes 4. It is unlikely, however, that such methods could be scaled up economically. High temperature processes that are based on extraction with liquid metals have been proposed. More recently, Japanese investigations have shown that treatment of the residues with lead and a glass-forming material causes extraction of the platinum group metals together with technetium and molybdenum, into the lead phase, leaving other impurities in the glass 6. Recovery from High Level Liquid Waste For thermal reactor fuel, which is the commonest type, about two thirds of the platinum group metals are found in the high level liquid waste, and various methods have been suggested for their separation and recovery. The range of the chemical elements present in high level liquid waste spans most Groups in the Periodic Table and the chemical problems of separation are in themselves difficult. Constraints are imposed by the presence of nitric acid 3M in the raffinate. In addition the solutions are radioactive and can only be processed in heavily shielded, and therefore expensive, plant. If the products are to be suitable for general use the separation from other radioactive fission products, for example, caesium must be essentially complete. The platinum group metals also have intrinsic radioactivity of their own, and the implications of this will be discussed later. These factors will make it very difficult to devise an economic separation route, even at the relatively high market values of the platinum group metals. Over the past three decades, several approaches have been suggested in the literature, but none of them has yet demonstrated the potential for application on a commercial scale. In the following paragraphs some recent advances in separation technology that might be applied to the problem are briefly discussed. Ruthenium Ruthenium can be separated from other metals in nitric acid solutions by oxidising it to the volatile tetroxide, for example with potassium periodate 2. From the data in Table I , it is clear that ruthenium and its daughter rhodium are the main contributors to the radioactivity of the platinum group metals fraction. The separation of ruthenium from rhodium and palladium might therefore be a worthwhile objective, perhaps as a preliminary step to the purification of the rhodium and palladium. It would be difficult, however, to achieve the necessary radiochemical decontamination by an oxidative distillation process. Solvent Extraction Methods Solvent

extraction methods could have potential for the extraction of rhodium and palladium. The selection of suitable extraction reagents requires consideration of the speciation and co-ordination chemistry of these metals in nitric acid solutions. Patel and co-workers have studied rhodium speciation in nitric acid solutions 7. Amine extractants, however, are generally used in the acidity range pH 2–4. In contrast, high level waste contains 1. Other systems for rhodium extraction have also been reported but suffer from various disadvantages. For example, a hydrocarbon solution of the cation exchanger dinonylnaphthalene sulphonic acid can be used as an extractant 10 ; backwashing is readily achieved with nitric acid or with a nitrite solution. Bar lines indicate species in the organic phase; HD represents dinonylnaphthalene sulphonic acid. The extraction mechanism here depends not on ligand exchange, which is generally slow for rhodium, but on inclusion in the micelle structures formed by association of the extractant in the hydrocarbon phase. Rhodium extraction is therefore rapid, but the reagent is not selective for rhodium. The extraction of palladium 11 and rhodium 12 by dialkyl sulphides is well known; but equilibration times for extraction are long a few hours making these extractants unsuitable for continuous counter-current solvent extraction processes. Substituted phosphine sulphides are another potentially useful class of reagents. Alkyl phosphorothioic triamides, RNH_3PS , extract a variety of metals, including palladium 13 , from mineral acid solutions. The last of these factors suggests the need for a batch extraction process, rather than continuous counter-current extraction, but the efficiency is not high enough to allow a satisfactory recovery by such a method. Tertiary phosphine sulphides 15 and oxides 16 have also been used to extract palladium. By careful choice of conditions, solvent extraction, with a sulphur based extractant, might be used to separate rhodium and palladium from high level liquid waste, but selectivity would be difficult to achieve. The processes would tend to be relatively complex, and plant costs would inevitably be high because of the shielding and remote handling equipment required for dealing with the fission product solutions. None of the processes discussed can currently be regarded as economically viable candidates for industrial use.

Utilisation of Fission-Derived Platinum Group Metals If a perfect chemical separation of the platinum group metals from other fission products and from each other could be carried out, the products obtained would still be radioactive because of the presence of active isotopes of the metals themselves, see Table I. This fact places severe restrictions on where and how the separated metals might be used, because of the obvious need to limit radiation doses to workers and to the general public. There is also a danger that if the radioactive metals from fission sources became mixed with material from natural sources, for example during metal recycling processes, the whole inventory of these naturally occurring metals could become contaminated with radioactivity. Ruthenium Ruthenium separated after cooling for five years would contain 3. Whenever Ru is present, an equal activity of Rh exists in equilibrium with it. Such ruthenium is clearly not suitable for widespread application. The metal would become essentially inactive after cooling for 30 to 50 years, but this long wait would involve economic penalties. Ruthenium is the lowest priced of the three platinum group metals under consideration It is used mainly in electrical applications and as an electrode material. It is not feasible that fission product ruthenium will be separated and used unless there is a dramatic change in the present situation. Rhodium Rhodium is an essential component of three-way catalyst systems for the control of automobile exhaust emissions, an application which accounts for 70 per cent of rhodium usage. Expanding demand for this application has led to steep rises in the price of rhodium. This situation makes rhodium an attractive candidate for separation. In the complete absence of ruthenium, rhodium would be free of Rh. However, the isotopes Rh and $m\text{Rh}$, although insignificant in mass terms, are sufficient to give separated rhodium a specific activity which is too high for general use in the motor industry, see Table I. A cooling period of about 50 years would remove the activity. Alternatively, isotopic separation processes could be considered. Even at the high market value of rhodium, economic separation and use of fission-derived material does not appear likely with the currently available technology.

Palladium The half-life of the active palladium isotope present in the fission-derived metal is so long 0. In addition, palladium is not as rare as the other platinum group metals, Table II , and currently it is relatively modestly priced For these reasons its separation from high level liquid waste will tend to be unattractive.

Conclusion The quantities of the three platinum group metals, palladium, rhodium and ruthenium, present in irradiated nuclear fuel are sufficient to constitute a useful resource of these important metals. This is particularly true of rhodium, which

is currently of great strategic and economic importance because of its use in vehicle exhaust emission control catalysts. Progress has been made on the development of chemical methods for extracting the platinum group metals from nuclear waste, but the chemical complexity and high radioactivity of the materials involved make it very difficult to devise an economically attractive process. Even if completely separated chemically from other fission products, platinum group metals derived from nuclear fuel would remain intrinsically radioactive. This would place a severe restriction on their utilisation, unless they were first stored for a period of say 50 years to allow the activity to decay sufficiently.

Chapter 3 : Radionuclide - Wikipedia

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February 11, Author: This issue has been widely reported , but the public remains unconcerned because of a popular misconception that there is no risk. I tested my own granite countertop at home and was shocked by the result, the warning alarm went off on the radiation monitor! Each slab of granite formed under different conditions, and even within a single slab the composition is not homogeneous. The fact is, some slabs of granite when tested exhibit extremely high radioactive emissions. Most slabs are more radioactive than alternative materials or the background level of radiation in your home. Granite tends to contain radioisotopes, primarily uranium, thorium and radium. Yes, you did read that correctly, and yes uranium is the fissile material used as the active ingredient of nuclear weapons, primarily uranium, and yes this isotope is found in granite. Potassium radioisotopes are also present in granite. These radioisotopes emit gamma rays, x-rays, as well as beta particles and alpha particles listed in descending order of harmfulness. When beta particles strike metal, it tends to release x-rays, especially denser metals like lead Bremsstrahlung radiation. The same radionuclides decay into radon gas , a dangerous invisible radioactive gas that is known to cause cancers, especially lung cancer. The British government acknowledges that breathing radon from granite is the second biggest cause of lung cancer , killing over people every year! In extreme cases, when radon is measured, an affected building may have to be evacuated and this is an internationally accepted safety measure. In short, your granite work top is irradiating your home with invisible rays of ionising radiation, as well as releasing hazardous radioactive gas that can accumulate if not ventilated. This may sound sensationalist, or alarmist, but it is not; it is literally true. Granite can be harmful. Some pieces of granite produce a lot more radiation and release a lot more radon than others. Pink granite as a rule-of-thumb is generally the most radioactive type of the rock , but certain slabs of any other type including black granite can exhibit equally dangerous levels of radioactivity. Nobody is monitoring this problem. Granite is sourced from geologically diverse areas all over the world without any checks for high radioactivity. The UK is slightly more proactive, with the HSE very open about the risks and other agencies working to raise awareness and monitor homes, especially in hotspots such as the southwest area of Britain. Nobody checks to see which slabs of granite are the most dangerous. Nobody is measuring radiation readings before or after installation of a new kitchen. Everyone behaves as though this is not a concern “ but it is, and people have every right to be aware of the risks. Geiger counters and radiation monitors are cheap, and people should use them. Chip in with your neighbours, get one, and share it. Teach your kids some science along the way. If you have a granite work surface or are considering getting one, it would be sensible to check its radiation levels “ ideally before you purchase. It would be negligent to ignore the danger, and irrational to assume that your piece of granite is safe.

Chapter 4 : Radioactive contamination - Wikipedia

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It is one in a series of Public Health Statements about hazardous substances and their health effects. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present. This public health statement tells you about cobalt and the effects of exposure. These sites make up the National Priorities List NPL and are the sites targeted for long-term federal cleanup activities. Stable cobalt has been found in at least of the 1, current or former NPL sites. Radioactive cobalt, as ^{60}Co , has been found in at least 13 of the 1, current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which cobalt is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure. When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact. External exposure to radiation may occur from natural or man-made sources. Naturally occurring sources of radiation are cosmic radiation from space or radioactive materials in soil or building materials. Man-made sources of radioactive materials are found in consumer products, industrial equipment, atom bomb fallout, and to a smaller extent from hospital waste and nuclear reactors. These factors include the dose how much , the duration how long , and how you come in contact with it. Cobalt is a naturally-occurring element that has properties similar to those of iron and nickel. It has an atomic number of There is only one stable isotope of cobalt, which has an atomic mass number of An element may have several different forms, called isotopes, with different weights depending on the number of neutrons that it contains. The isotopes of an element, therefore, have different atomic mass numbers [number of protons and neutrons], although the atomic number [number of protons] remains the same. However, there are many unstable or radioactive isotopes, two of which are commercially important, cobalt and cobalt, also written as Co or ^{60}Co and Co or ^{57}Co , and read as cobalt sixty and cobalt fifty-seven. All isotopes of cobalt behave the same chemically and will therefore have the same chemical behavior in the environment and the same chemical effects on your body. However, isotopes have different mass numbers and the radioactive isotopes have different radioactive properties, such as their half-life and the nature of the radiation they give off. The half-life of a cobalt isotope is the time that it takes for half of that isotope to give off its radiation and change into a different isotope. After one half-life, one-half of the radioactivity is gone. After a second half-life, one-fourth of the original radioactivity is left, and so on. Radioactive isotopes are constantly changing into different isotopes by giving off radiation, a process referred to as radioactive decay. The new isotope may be a different element or the same element with a different mass. Small amounts of cobalt are naturally found in most rocks, soil, water, plants, and animals, typically in small amounts. Cobalt is also found in meteorites. Elemental cobalt is a hard, silvery grey metal. However, cobalt is usually found in the environment combined with other elements such as oxygen, sulfur, and arsenic. Small amounts of these chemical compounds can be found in rocks, soil, plants, and animals. Cobalt is even found in water in dissolved or ionic form, typically in small amounts. Ions are atoms, collections of atoms, or molecules containing a positive or negative electric charge. A biochemically important cobalt compound is vitamin B12 or cyanocobalamin. Vitamin B12 is essential for good health in animals and humans. Cobalt is not currently mined in the United States, but has been mined in the past. Therefore, we obtain cobalt and its other chemical forms from imported materials and by recycling scrap metal that contains cobalt. Cobalt metal is usually mixed with other metals to form alloys, which are harder or more resistant to wear and corrosion. These alloys are used in a number of military and industrial applications such as aircraft engines, magnets, and grinding and

cutting tools. They are also used in artificial hip and knee joints. Cobalt compounds are used as colorants in glass, ceramics, and paints, as catalysts, and as paint driers. Cobalt colorants have a characteristic blue color; however, not all cobalt compounds are blue. Cobalt compounds are also used as trace element additives in agriculture and medicine. Cobalt can also exist in radioactive forms. A radioactive isotope of an element constantly gives off radiation, which can change it into an isotope of a different element or a different isotope of the same element. This newly formed nuclide may be stable or radioactive. This process is called radioactive decay. It is produced by bombarding natural cobalt, ^{59}Co , with neutrons in a nuclear reactor. The half-life of ^{60}Co is 5. The decay is accompanied by the emission of high energy radiation called gamma rays. Another important cobalt isotope, ^{58}Co , is produced when nickel is exposed to a source of neutrons. Since nickel is used in nuclear reactors, ^{58}Co may be unintentionally produced and appear as a contaminant in cooling water released by nuclear reactors. Quantities of radioactive cobalt are normally measured in units of radioactivity curies or becquerels rather than in units of mass grams. The becquerel Bq is a new international unit, and the curie Ci is the traditional unit; both are currently used. A becquerel is the amount of radioactive material in which 1 atom transforms every second, and a curie is the amount of radioactive material in which 37 billion atoms transform every second. For an overview of basic radiation physics, chemistry, and biology see Appendix D of the cobalt profile. Cobalt may enter the environment from both natural sources and human activities. Cobalt occurs naturally in soil, rock, air, water, plants, and animals. It may enter air and water, and settle on land from windblown dust, seawater spray, volcanic eruptions, and forest fires and may additionally get into surface water from runoff and leaching when rainwater washes through soil and rock containing cobalt. Soils near ore deposits, phosphate rocks, or ore smelting facilities, and soils contaminated by airport traffic, highway traffic, or other industrial pollution may contain high concentrations of cobalt. Small amounts of cobalt may be released into the atmosphere from coal-fired power plants and incinerators, vehicular exhaust, industrial activities relating to the mining and processing of cobalt-containing ores, and the production and use of cobalt alloys and chemicals. Cobalt cannot be destroyed in the environment. It can only change its form or become attached or separated from particles. Cobalt released from power plants and other combustion processes is usually attached to very small particles. Cobalt contained in windborne soil is generally found in larger particles than those released from power plants. These large particles settle to the ground or are washed out of the air by rain. Cobalt that is attached to very small particles may stay in the air for many days. Cobalt released into water may stick to particles in the water column or to the sediment at the bottom of the body of water into which it was released, or remain in the water column in ionic form. The specific fate of cobalt will depend on many factors such as the chemistry of the water and sediment at a site as well as the cobalt concentration and water flow. Cobalt deposited on soil is often strongly attached to soil particles and therefore would not travel very far into the ground. However, the form of the cobalt and the nature of the soil at a particular site will affect how far cobalt will penetrate into the soil. Both in soil and sediment, the amount of cobalt that is mobile will increase under more acidic conditions. Ultimately, most cobalt ends up in the soil or sediment. Plants can accumulate very small amounts of cobalt from the soil, especially in the parts of the plant that you eat most often, such as the fruit, grain, and seeds. While animals that eat these plants will accumulate cobalt, cobalt is not known to biomagnify produce increasingly higher concentrations up the food chain. Therefore, vegetables, fruits, fish, and meat that you consume will generally not contain high amounts of cobalt. Cobalt is an essential element, required for good health in animals and humans, and therefore, it is important that foodstuffs contain adequate quantities of cobalt. Although these isotopes are not produced by nuclear fission, small amounts of these radioisotopes are also produced by the neutron interaction with the structural materials found in the reactor of nuclear plants, and are produced during the routine operation of nuclear plants. Small amounts may be released to the environment as contaminants in cooling water or in radioactive waste. Since these isotopes are not fission products, they are not produced in nuclear weapons testing and are not associated with nuclear fallout. In the environment, radioactive isotopes of cobalt will behave chemically like stable cobalt. However, ^{60}Co and ^{58}Co will also undergo radioactive decay according to their respective half-lives, 5. Cobalt is widely dispersed in the environment in low concentrations. You may be exposed to small amounts of cobalt by breathing air, drinking water, and eating food containing it. Children

may also be exposed to cobalt by eating dirt. You may also be exposed by skin contact with soil, water, cobalt alloys, or other substances that contain cobalt. Analytical methods used by scientists to determine the levels of cobalt in the environment generally do not determine the specific chemical form of cobalt present. Therefore, we do not always know the chemical form of cobalt to which a person may be exposed. Similarly, we do not know what forms of cobalt are present at hazardous waste sites. Some forms of cobalt may be insoluble or so tightly attached to particles or embedded in minerals that they are not taken up by plants and animals. Other forms of cobalt that are weakly attached to particles may be taken up by plants and animals. Soils containing less than about 3 ppm of cobalt are considered cobalt-deficient because plants growing in them do not have sufficient cobalt to meet the dietary requirements of cattle and sheep. Such cobalt-deficient soils are found in some areas in the southeast and northeast parts of the United States. On the other hand, soils near cobalt-containing mineral deposits, mining and smelting facilities, or industries manufacturing or using cobalt alloys or chemicals may contain much higher levels of cobalt.

Chapter 5 : Radiation Effects in Steel

Metals can always become radioactive by exposure to neutron radiation. This is called neutron activation. Depending on number of nuclear reactions which occur in the metal, or element, the radioactivity will change.

Metal powder at room temperature actually does a good job of absorbing microwave radiation. When it does so, it heats up. This is generally how the microwave pouches, such as come with hot pockets or pot pies, work; though, they sometimes use a form of ceramic instead, with the same effect of generating heat to brown the outside of the food. These pouches and containers meant for browning are known as susceptors. This creates microwaves in the oven that have nothing to absorb them. This standing wave is reflected back and forth within the microwave, between the tube and the cooking chamber, and will eventually burn out the magnetron. This same effect can occur when cooking dehydrated food or, as noted previously, food wrapped in some sort of metal where there is very little to absorb the emitted microwaves. The type of radiation emitted by microwave ovens is non-ionizing. Radar and GPS also operate using radiation in the microwave spectrum. Electromagnetic waves were predicted by James Clerk Maxwell in His device used a horse trough; Leyden jars; a zinc gutter worked as an antenna ; and a wrought iron point spark. Basically, molecules such as water molecules are electric dipoles. This means that they have a positive charge and a negative charge on opposite ends. Thus, they will rotate themselves rapidly when trying to align themselves with the alternating electric field from the microwaves. As these molecules rub against each other, they heat up and, as they do so, they themselves also become part of the cooking process, heating up molecules around them that may not be absorbing much, or any, of the microwaves. Microwaves are not nearly as efficient at heating frozen food due to the fact that the molecules are not free to rotate or move. Microwaves actually heat from the outside in, very similar to other heating methods. Thus, the liquid inside will appear to heat up first. This is why, with frozen objects, the center might remain frozen and the outer layer somewhat cool, while the layer just under the crust may be super hot. The particular band of microwaves produced by typical microwave ovens 2. Within the available frequencies that are not set aside for communication, 2. Rather, it simply changes the duty cycle of the magnetron. In other words, it turns on and off at a different rate. A convection oven is basically just a conventional microwave that also has a way to brown food like a traditional oven. In order to provide this browning effect, the convection oven may use traditional oven heating elements or might use something such as a high powered halogen bulb. The ability to use microwaves as a heating device for food was originally discovered by an engineer by the name of Percy Spencer. Spencer was working on building magnetrons for radar sets. One day, he was standing in front of an active radar set when he noticed the candy bar he had in his pocket melted. Upon noticing this, Spencer made the monumental mistake of telling other people instead of keeping it to himself and working on it on his own. The first one he heated intentionally was popcorn. The second was an egg, which ended up exploding in the face of one of his co-workers. Spencer then created what we might call the first true microwave oven by attaching a high density electromagnetic field generator which would then shoot into a metal box, so that the electromagnetic waves would have no way to escape and the oven would be much more efficient and safe. He then placed various food items in the box and monitored their temperature to observe the effect. The company Spencer was working for, Raytheon, then filed a patent on October 8, for a microwave cooking oven, eventually named the Radarange. This first microwave oven was about 6 feet tall and weighed around pounds. This voltage will exceed the dielectric breakdown of air, which is about 3 megavolts per meter. The air then forms a kind of conductive plasma, which is the spark you see. This, in turn, makes the fork an even more effective antenna for the microwaves, worsening the problem. In the s, about telephone calls could be run through a single microwave channel via multiplexing. The distance between hops was typically around miles. The additional cost of transmitting this way was a large part of why long distance was so expensive historically. Although, satellite systems are essentially just a space-based version of this same thing.

Chapter 6 : ATSDR - Public Health Statement: Cobalt

The elements are then organized into sections: metals, nonmetals, and metalloids. Metals can be divided into alkali metals, alkaline earth metals, and transition metals. Nonmetals can be broken down into families: carbon, nitrogen family, oxygen family, halogen family, noble gases, and hydrogen.

Natural[edit] On Earth, naturally occurring radionuclides fall into three categories: Radionuclides are produced in stellar nucleosynthesis and supernova explosions along with stable nuclides. Most decay quickly but can still be observed astronomically and can play a part in understanding astronomic processes. Some radionuclides have half-lives so long many times the age of the universe that decay has only recently been detected, and for most practical purposes they can be considered stable, most notably bismuth It is possible decay may be observed in other nuclides adding to this list of primordial radionuclides. Secondary radionuclides are radiogenic isotopes derived from the decay of primordial radionuclides. They have shorter half-lives than primordial radionuclides. They arise in the decay chain of the primordial isotopes thorium, uranium and uranium Examples include the natural isotopes of polonium and radium. Cosmogenic isotopes , such as carbon , are present because they are continually being formed in the atmosphere due to cosmic rays. Secondary radionuclides will occur in proportion to their half-lives, so short-lived ones will be very rare. Thus polonium can be found in uranium ores at about 0. Nuclear fission[edit] Radionuclides are produced as an unavoidable result of nuclear fission and thermonuclear explosions. The process of nuclear fission creates a wide range of fission products , most of which are radionuclides. Further radionuclides can be created from irradiation of the nuclear fuel creating a range of actinides and of the surrounding structures, yielding activation products. This complex mixture of radionuclides with different chemistries and radioactivity makes handling nuclear waste and dealing with nuclear fallout particularly problematic. Artificial nuclide americium emitting alpha particles inserted into a cloud chamber for visualisation Synthetic radionuclides are deliberately synthesised using nuclear reactors , particle accelerators or radionuclide generators: As well as being extracted from nuclear waste, radioisotopes can be produced deliberately with nuclear reactors, exploiting the high flux of neutrons present. These neutrons activate elements placed within the reactor. A typical product from a nuclear reactor is iridium The elements that have a large propensity to take up the neutrons in the reactor are said to have a high neutron cross-section. Particle accelerators such as cyclotrons accelerate particles to bombard a target to produce radionuclides. Cyclotrons accelerate protons at a target to produce positron-emitting radionuclides, e. Radionuclide generators contain a parent radionuclide that decays to produce a radioactive daughter. The parent is usually produced in a nuclear reactor. A typical example is the technetium generator used in nuclear medicine. The parent produced in the reactor is molybdenum Uses[edit] Radionuclides are used in two major ways: In biology , radionuclides of carbon can serve as radioactive tracers because they are chemically very similar to the nonradioactive nuclides, so most chemical, biological, and ecological processes treat them in a nearly identical way. One can then examine the result with a radiation detector, such as a Geiger counter , to determine where the provided atoms were incorporated. For example, one might culture plants in an environment in which the carbon dioxide contained radioactive carbon; then the parts of the plant that incorporate atmospheric carbon would be radioactive. Radionuclides can be used to monitor processes such as DNA replication or amino acid transport. In nuclear medicine , radioisotopes are used for diagnosis, treatment, and research. Radioactive chemical tracers emitting gamma rays or positrons can provide diagnostic information about internal anatomy and the functioning of specific organs, including the human brain. Radioisotopes are also a method of treatment in hemopoietic forms of tumors; the success for treatment of solid tumors has been limited. More powerful gamma sources sterilise syringes and other medical equipment. In food preservation , radiation is used to stop the sprouting of root crops after harvesting, to kill parasites and pests, and to control the ripening of stored fruit and vegetables. In industry , and in mining , radionuclides are used to examine welds, to detect leaks, to study the rate of wear, erosion and corrosion of metals, and for on-stream analysis of a wide range of minerals and fuels. In spacecraft and elsewhere, radionuclides are used to provide power and heat, notably through radioisotope thermoelectric generators

RTGs. In astronomy and cosmology radionuclides play a role in understanding stellar and planetary process. In particle physics , radionuclides help discover new physics physics beyond the Standard Model by measuring the energy and momentum of their beta decay products. In geology , archaeology , and paleontology , natural radionuclides are used to measure ages of rocks, minerals, and fossil materials. The following table lists properties of selected radionuclides illustrating the range of properties and uses.

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Ionizing radiation refers to radioactive particles, such as alpha and beta particles, or electromagnetic waves, such as gamma or ultraviolet rays, which have sufficient energy to detach electrons off of atoms to create ions, hence the name "ionizing radiation."

Surface contamination[edit] Surface contamination may either be fixed or "free". In the case of fixed contamination, the radioactive material cannot by definition be spread, but its radiation is still measurable. In the case of free contamination there is the hazard of contamination spread to other surfaces such as skin or clothing, or entrainment in the air. A concrete surface contaminated by radioactivity can be shaved to a specific depth, removing the contaminated material for disposal. For occupational workers controlled areas are established where there may be a contamination hazard. Access to such areas is controlled by a variety of barrier techniques, sometimes involving changes of clothing and foot wear as required. The contamination within a controlled area is normally regularly monitored. Radiological protection instrumentation RPI plays a key role in monitoring and detecting any potential contamination spread, and combinations of hand held survey instruments and permanently installed area monitors such as Airborne particulate monitors and area gamma monitors are often installed. Detection and measurement of surface contamination of personnel and plant is normally by Geiger counter, scintillation counter or proportional counter. Proportional counters and dual phosphor scintillation counters can discriminate between alpha and beta contamination, but the Geiger counter cannot. Scintillation detectors are generally preferred for hand held monitoring instruments, and are designed with a large detection window to make monitoring of large areas faster. Geiger detectors tend to have small windows, which are more suited to small areas of contamination. Exit monitoring[edit] The spread of contamination by personnel exiting controlled areas in which nuclear material is used or processed is monitored by specialised installed exit control instruments such as frisk probes, hand contamination monitors and whole body exit monitors. These are used to check that persons exiting controlled areas do not carry contamination on their body or clothes. In the United Kingdom the HSE has issued a user guidance note on selecting the correct portable radiation measurement instrument for the application concerned. The UK NPL publishes a guide on the alarm levels to be used with instruments for checking personnel exiting controlled areas in which contamination may be encountered. Airborne particulate radioactivity monitoring The air can be contaminated with radioactive isotopes in particulate form, which poses a particular inhalation hazard. Respirators with suitable air filters, or completely self-contained suits with their own air supply can mitigate these dangers. Airborne contamination is measured by specialist radiological instruments that continuously pump the sampled air through a filter. Airborne particles accumulate on the filter and can be measured in a number of ways: The filter paper is periodically manually removed to an instrument such as a "scaler" which measures any accumulated radioactivity. The filter paper is static and is measured in situ by a radiation detector. The filter is a slowly moving strip and is measured by a radiation detector. These are commonly called "moving filter" devices and automatically advance the filter to present a clean area for accumulation, and thereby allow a plot of airborne concentration over time. Commonly a semiconductor radiation detection sensor is used that can also provide spectrographic information on the contamination being collected. A particular problem with airborne contamination monitors designed to detect alpha particles is that naturally occurring radon can be quite prevalent and may appear as contamination when low contamination levels are being sought. Modern instruments consequently have "radon compensation" to overcome this effect. See the article on Airborne particulate radioactivity monitoring for more information. Internal human contamination[edit] Main article: Committed dose Radioactive contamination can enter the body through ingestion, inhalation, absorption, or injection. This will result in a committed dose of radiation. For this reason, it is important to use personal protective equipment when working with radioactive materials. Radioactive contamination may also be ingested as the result of eating contaminated plants and animals or drinking contaminated water or milk from exposed animals. Following a major contamination incident, all potential pathways of internal exposure should be considered. Successfully used on Harold McCluskey, chelation

therapy and other treatments exist for internal radionuclide contamination. In some cases of large areas of contamination, the contamination may be mitigated by burying and covering the contaminated substances with concrete, soil, or rock to prevent further spread of the contamination to the environment. Department of Energy DOE and the commercial nuclear industry for decades to minimize contamination on radioactive equipment and surfaces and fix contamination in place. Strippable coating products are loosely adhered paint-like films and are used for their decontamination abilities. The residual radioactive contamination on the surface is significantly reduced once the strippable coating is removed. Modern strippable coatings show high decontamination efficiency and can rival traditional mechanical and chemical decontamination methods. Decontamination gels work in much the same way as other strippable coatings. The results obtained through the use of contamination control products is variable and depends on the type of substrate, the selected contamination control product, the contaminants, and the environmental conditions e. The national government is under pressure to clean up radioactivity due to the Fukushima nuclear accident of March from as much land as possible so that some of the , displaced people can return. Stripping out the key radioisotope threatening health caesium from low level waste could also dramatically decrease the volume of waste requiring special disposal. One being investigated is termed hydrothermal blasting. The caesium is broken away from soil particles and then precipitated with ferric ferricyanide Prussian blue. It would be the only component of the waste requiring special burial sites. To help with protection of people living in geographical areas which have been radioactively contaminated the International Commission on Radiological Protection has published a guide: Elements which contain at least one stable isotope. Low-level contamination[edit] The hazards to people and the environment from radioactive contamination depend on the nature of the radioactive contaminant, the level of contamination, and the extent of the spread of contamination. Low levels of radioactive contamination pose little risk, but can still be detected by radiation instrumentation. Low levels may be reported in counts per minute using a scintillation counter. In the case of low-level contamination by isotopes with a short half-life, the best course of action may be to simply allow the material to naturally decay. Longer-lived isotopes should be cleaned up and properly disposed of, because even a very low level of radiation can be life-threatening when in long exposure to it. Facilities and physical locations that are deemed to be contaminated may be cordoned off by a health physicist and labeled "Contaminated area. High-level contamination[edit] High levels of contamination may pose major risks to people and the environment. People can be exposed to potentially lethal radiation levels, both externally and internally, from the spread of contamination following an accident or a deliberate initiation involving large quantities of radioactive material. The biological effects of external exposure to radioactive contamination are generally the same as those from an external radiation source not involving radioactive materials, such as x-ray machines, and are dependent on the absorbed dose. When radioactive contamination is being measured or mapped in situ , any location that appears to be a point source of radiation is likely to be heavily contaminated. A highly contaminated location is colloquially referred to as a "hot spot. In a contaminated facility, hot spots may be marked with a sign, shielded with bags of lead shot , or cordoned off with warning tape containing the radioactive trefoil symbol. The radiation warning symbol trefoil Alpha radiation consists of helium-4 nucleus and is readily stopped by a sheet of paper. Beta radiation, consisting of electrons , is halted by an aluminium plate. Gamma radiation is eventually absorbed as it penetrates a dense material. Lead is good at absorbing gamma radiation, due to its density. The hazard from contamination is the emission of ionising radiation. The principal radiations which will be encountered are alpha, beta and gamma, but these have quite different characteristics. They have widely differing penetrating powers and radiation effect, and the accompanying diagram shows the penetration of these radiations in simple terms. For an understanding of the different ionising effects of these radiations and the weighting factors applied, see the article on absorbed dose. Radiation monitoring involves the measurement of radiation dose or radionuclide contamination for reasons related to the assessment or control of exposure to radiation or radioactive substances, and the interpretation of the results. The methodological and technical details of the design and operation of environmental radiation monitoring programmes and systems for different radionuclides, environmental media and types of facility are given in IAEA Safety Standards Series No.