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RADIATION SAFETY COURSE
for the
LPA-1
XRF Inspection System

Thank you for participating in the PROTEC Instrument corporation LPA manufacturer's radiation safety training. This training is required by anyone who will be operating a PROTEC XRF Lead Paint Spectrum Analyzer. The training will cover many topics such as basic physics, radiation safety, and XRF technologies. At the end of each training module, you will be required to answer a few questions to ensure that you are understanding the required information. At the conclusion of the training, your name and company information will be submitted to PROTEC and you will be issued a training certificate. Please note that all training modules must be completed in order for you to receive your certificate.

Overview

This radiation safety training course provides participants with:

(1) Fundamental knowledge of radiation and safety
(2) Understanding of XRF technology, theory and application
(3) Licensing and other requirements

This course is in addition to any other radiation safety training that may be required by the State, corporation, and other organizations.

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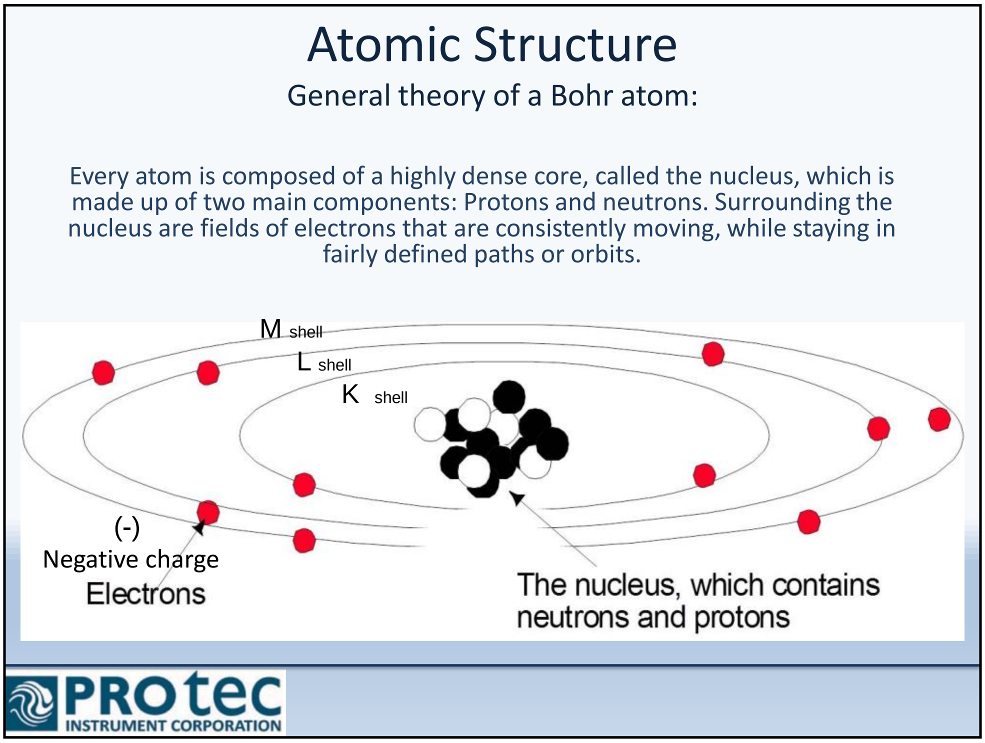
There are three specific topics that will be covered in this training:

- Fundamental knowledge of radiation and the protocol for working safely in the presence of radiation, will be addressed because these machines contain a small amount of radioactive material.
- Theory and application of XRF technology with lead paint inspection.
- Device licensing and other regulations you're likely to encounter, in owning an XRF device. Remember, this course is in addition to any other radiation safety training that may be required by the State, corporation or other organizations.



To understand radiation safety and XRF methods, you should have a basic understanding of the atomic structure. XRF technology requires that atoms are disturbed. When an atom is disturbed, it reacts, and by measuring that reaction, we are able to determine which atom is disturbed, as well as how many of that particular atom exist.

Every atom is basically composed of a highly dense center, or core, called the nucleus. The nucleus is made up of two main components: protons and neutrons. Surrounding the nucleus are fields of electrons which are always moving, while also staying in fairly defined paths or orbits. These paths are known as shells. Each of the shells is well-defined, based on its energy level and is named K, L, M, N, O, and so on.

Atomic Structure

General theory of a Bohr atom:

Electron orbital shells and their importance:

Electrons travel in orbits around the nucleus. There are several orbits, also called shells, that the electrons can occupy. Based on their energy, some can be removed from their shells by bombarding them with radiation.

	Charge (e)	Mass (kg)	Mass (amu)	Rest Energy (MeV)
Proton	+1	1.6726×10^{-27}	1.0073	938.27
Neutron	0	1.6749×10^{-27}	1.0087	939.57
Electron	-1	9.1094×10^{-31}	0.000549	0.511

- **Electrons** – negative charge (-), orbit the atom and are responsible for chemical bonds.
- **Protons** – positive charge (+), are located in the nucleus and determine the element.
- **Neutrons** – neutral charge (0), are located in the nucleus and determine the isotope.

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The first shell, “K-shell,” is the closest to the nucleus. This shell can only contain two electrons. The next shell out is the L Shell, it has four electrons, the next shell has eight, next has sixteen, and so on.

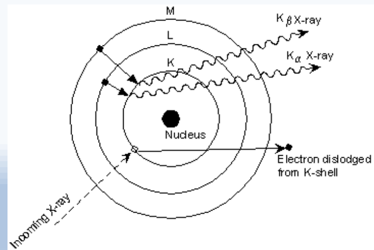
The electrical characteristic of the electron is a negative charge and the proton is positively charged. In Physics 101, you ought to have learned that electrons with similar charges will repel each other, and opposite charges attract. The attraction of these opposite charges is what allows the electrons and protons to form an atom.

Atomic Structure

Binding Energy, Ionization Energy

The binding energy is the amount of energy that it takes to remove the electron from its orbit around the nucleus.

K-shell, L-shell, M-shell: Every element in nature, if you excite, or disturb, their electrons, will send out its own characteristic radiations that are fairly well-defined. Lead has many of these, based on its amount of shells. It has K-shell X-rays, L-shell X-rays, M-shell X-rays, N-shell X-rays, and so on. The two most common are K's and L's.



Every electron is held in place by this specific amount of energy. So, to displace one of these electrons, you will need to add the same amount of energy or more, that is required for the electron to be held in place by the atom. This energy is referred to as "binding energy", which is defined by the amount of energy that it takes to remove the electron from its orbit around the nucleus.

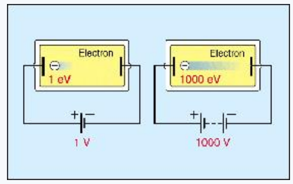
If an electron orbit is close to the nucleus, it is under more force, requiring more energy to release it. As an electron orbit gets further away from the nucleus, the amount of binding energy decreases. This is the fundamental groundwork of X-ray Fluorescence (XRF) Technology. Using XRF technology, we can remove an electron from an atom and measure that energy to identify the atom. Atoms are identified by how many protons exist in their nucleus, and that number is known as the atomic number. The atomic number for Lead is 82, because it contains 82 protons.

Atomic Structure

Electron Volt

An **Electron Volt** is defined as the *amount of kinetic energy an electron has after it travels 1 meter over a voltage potential of 1 Volt*.
Examples: ev, keV, meV

- 1 eV is a very small amount of energy, so as with units of activity, it is often measured in kilo electron volts (keV) and mega electron volts (meV). The source inside the PROTEC LPA-1, Co-57, emits a gamma ray energy of 122 keV.

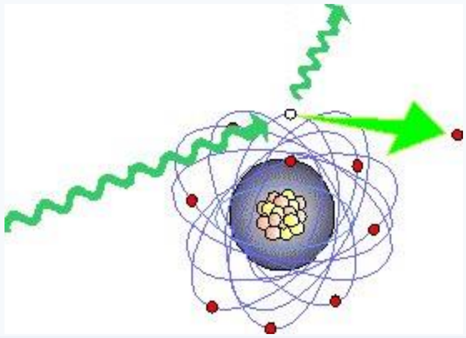


Binding energy is measured by the unit called an electron volt, or eV, which is a very small amount of energy. KeV is used to indicate one thousand electron volts. MeV, or Mega electron volts, indicates a million eV's. For example, a medical X-ray is generally between 60 to 100 KeV. Cobalt 57, which is the source used in the PROTEC XRF machine, has several lines of energy. The two most common for this purpose are 122 Kev, which occur about 85% of the time, and 136 KeV, which occurs about 11% of the time.

Radiation and its properties

Radiation is a form of energy. It is the transformation of one form of energy to another. Radiation can be categorized in many ways, but the most common are:

- Based on energy
- Based on type



When categorizing radiation based on energy, there are two forms:

Ionizing energy * Non-ionizing energy

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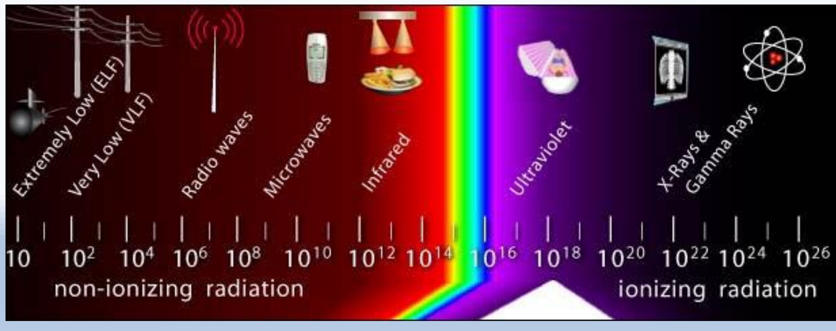
Radiation is a form of energy, and radioactive material is defined as a collection of unstable atoms.

It is the transformation from one form of energy to another. Radiation can be categorized in many ways, most commonly based on energy, and also based on type. When categorizing radiation based on energy, there are two forms: ionizing energy and non-ionizing energy.

Radiation and properties

Ionizing (*X-rays, alpha, beta, and gamma rays*) – Ionizing radiation creates ion pairs by breaking chemical bonds. These ions go on to cause damage in material and tissue. This is the radiation that is of concern when working with radioactive materials.

Non-ionizing *(Sunlight, microwave, radio waves)* – Energy in this form will not create ions that can cause damage to material or tissue but may have other effects.



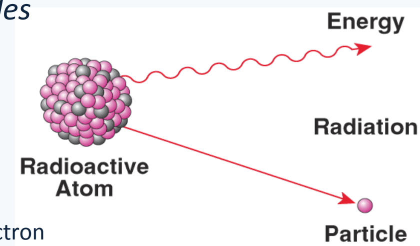
Ionizing radiation has enough energy to release an electron from its field, releasing ions. It can damage human tissue by creating ion pairs in the body.

X-Rays, Gamma-rays, Alphas, Betas, Neutrons, and Protons, are all forms of ionizing radiation. This is the type of radiation XRF instruments use for analysis.

When non-ionizing radiation hits the body or the atom, it will be absorbed, but it does not have enough energy to release the electrons out of the body or out of the atom. Examples of non-ionizing radiation are visible light, infrared light, microwave radiation, and radio waves.

Radiation and properties

Particles



Particles (Alpha, Beta, Protons, Neutrons):

- Have a mass
- May or may not have velocity
- Interact with both the nucleus and the electron

Electromagnetic Energy (X-Ray, Gamma Ray)

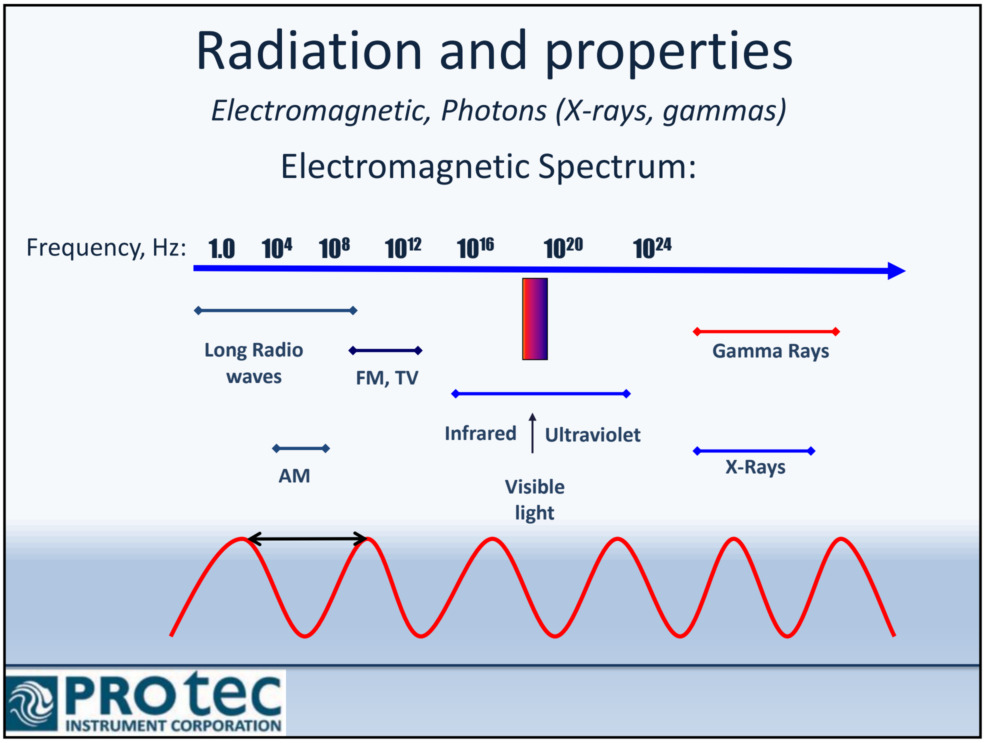
- Does *not* have a mass
- Does have a velocity, in that it moves at the speed of light
- Interacts mainly with orbital electrons and causes them to be ejected from the nucleus.
- Kinetic energy, the energy of a particle, is determined by the equation E=mv2 /2 (energy increases by the square of the distance). So if you double its speed, you quadruple the kinetic energy it has. This energy gets deposited in materials, to create ions.

A particle, by definition, is a type of matter, meaning that it has a mass. And for a particle to have energy, referred to here as kinetic energy, it has to move, or have velocity.

Kinetic energy is equal to one half of the mass, times the square of the particle's velocity. This can be applied to alpha rays, betas, neutrons, and protons. This type of radiation is simple - The faster an object is moving, the greater the impact. Therefore, the higher the speed of these particles, the more energy they have.

For example, alpha rays are nothing but the nucleus of a helium atom. The helium atom has an atomic mass of four: Two protons and two neutrons. Shake all of these electrons out, keeping just the nucleus, and it becomes an alpha ray. An alpha particle is an example of a heavy charged-particle that can cause damage to the body if alpha-emitting materials are ingested.

These are very easy to block; for example, a piece of paper will block the majority of alpha rays, but if they get inside your body, they can do a lot of damage, because of it's high mass. On the biological scale, alpha rays have the highest damaging power.



Electromagnetic radiation has similar movement patterns to a particle. Like a particle, it travels in a straight line, and it only moves with one speed: the speed of light. If you slow it down or catch it, it ceases to exist. Therefore, it has no resting mass.

But electromagnetic radiation behaves like a wave, because along with having a frequency, electromagnetic radiation also has a wavelength. These bundles of energy are moving with the speed of light in the same direction and are also oscillating, which means they have a frequency, called photons. Any time you refer to electromagnetic radiation, X-rays, gamma rays, visible light, microwave, infrared, or ultraviolet, these are referred to as photons. A photon is defined as a bundle of energy that is moving with the speed of light. As it moves, it oscillates, it has a frequency and the higher the frequency, the more energy it contains.

Radiation and Properties

Maximum Distance Traveled per Radiation Type

	Mass (amu)	Charge	Distance Traveled in Air
Alpha	4.0000	+2	few centimeters
Beta Plus	0.0005	+1	few meters
Beta Minus	0.0005	-1	few meters
Gamma	0.0000	0	many meters
X-Rays	0.0000	0	many meters
Neutron	1.0000	0	many meters

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Different types of radiation are capable of traveling through the air to different distances.

As you can see from the chart, Alphas and Betas will only travel a short distance, while Gamma, X-rays and Neutrons can travel a further distance.

Radioactivity: The Basics

There are 2 types of Radiation:

- **Natural (NORM):** Naturally-Occurring Radioactive Material.
  - Includes cosmic radiation from the sun and terrestrial radiation from the ground (radon).

- **Man-made (NARM):** Naturally-occurring Accelerator-produced Radioactive Material.
  - Includes nuclear power, radiographic medical procedures, and analytical instrumentation.

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There are two types of radioactive material: Naturally-occurring and man-made.

Examples of Naturally-Occurring Radioactive Material include cosmic radiation from the sun, and terrestrial radiation from the ground, such as radon.

The other type of radioactivity is “accelerator-produced”, or ‘NARM’ which stands for Naturally-occurring Accelerator-produced Radioactive Material. Nearly any material can be bombarded with radiation; eventually a neutron, a proton, or an electron will be released from an atom, rendering it radioactive.

Radioactivity: The Basics

Radioactive sources can be defined by their **level of strength**.
The **strength of a source** is defined by its **activity**, which is
the **number of disintegrations** in a **certain amount of time**.

The more disintegrations that occur, the more radioactive the material is,

and the more energy being released in that time.

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Radioactive sources are defined by their level of activity strength. The strength is defined by its activity, which is the number of disintegrations in a specific amount of time. The more disintegrations that occur, the more energy is being released at that moment, and thus the more radioactive the material.

Radioactivity

Units of Measure

Units of radioactivity are typically listed as *Becquerels* or Curies.

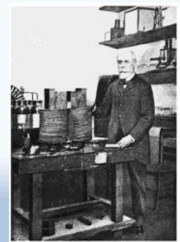
- 1 Becquerel = *One disintegration per second*.
- 1 Curie = *3.7x10*^{10} *Becquerels*.

Prefixes: Micro * Milli * Mega

i.e: megaBecquerel (MBq)

milliCuries (mCi)

microCurie (µci)



In the case of the XRF devices, units are millicuries or megaBacquerel.

Radioactivity can be measured by two types of units: Becquerel and Curie units. The Sievert symbol, or Sv, is a third method, which is used to indicate SI Units, or “Systems International”.

Historically, the unit for radioactivity is based on Curie, named after the Polish scientist, Madame Curie.

One Curie is 3.7 x 10 to the 10th power disintegration per second.

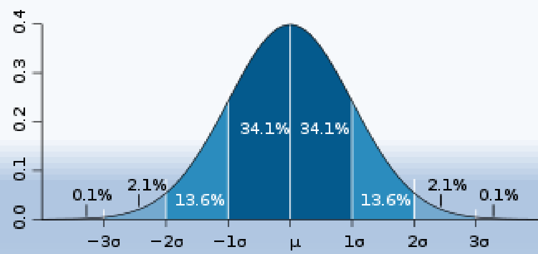
A 1 Curie source contains a large amount of radioactive material. Therefore, small sources like the one used in a handheld XRF machine, use milliCurie to measure the radioactivity.

A milli of something is 1/1,000th. For example, the source utilized by the Protec XRF devices contains a 12 milliCurie source.

The conversion formula between these two units of measure is 1 milliCurie, equals 37 mega-Becqueral, where mega- means a million of something. So in the case of the PROTEC XRF system, 12 Millicurie is equal to 444 mega-Becqueral.

Radioactivity
Statistical nature of radioactive process

Radioactive decay is a random process, but when it occurs many times over, a pattern can be derived from it.



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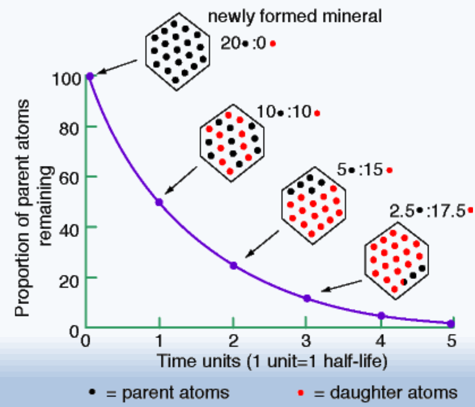
This is a “normal” curve, also known as a natural curve, because all events in nature follow this curve. Events that are considered normal occur most often, and moving away from the norm on either end of the curve, the odds of occurrence drop.

So, when we say that radioactivity is a ‘random’ process, what does that mean? This means that radioactivity is the spontaneous decay of an unstable nucleus, and that it is impossible to predict when a particular atom will decay. However, the chance that a given atom will decay is constant over time. If a source is giving out ten thousand gamma rays, then ten thousand is the average value, or the norm, for that source.

Radioactivity

Half-life, decay

Half-life: The amount of time will it take for a source to lose **half** of its original activity. For example, if a source is releasing ten thousand gamma rays per second, and it decays by one half-life, it will be releasing five thousand gamma rays per second.



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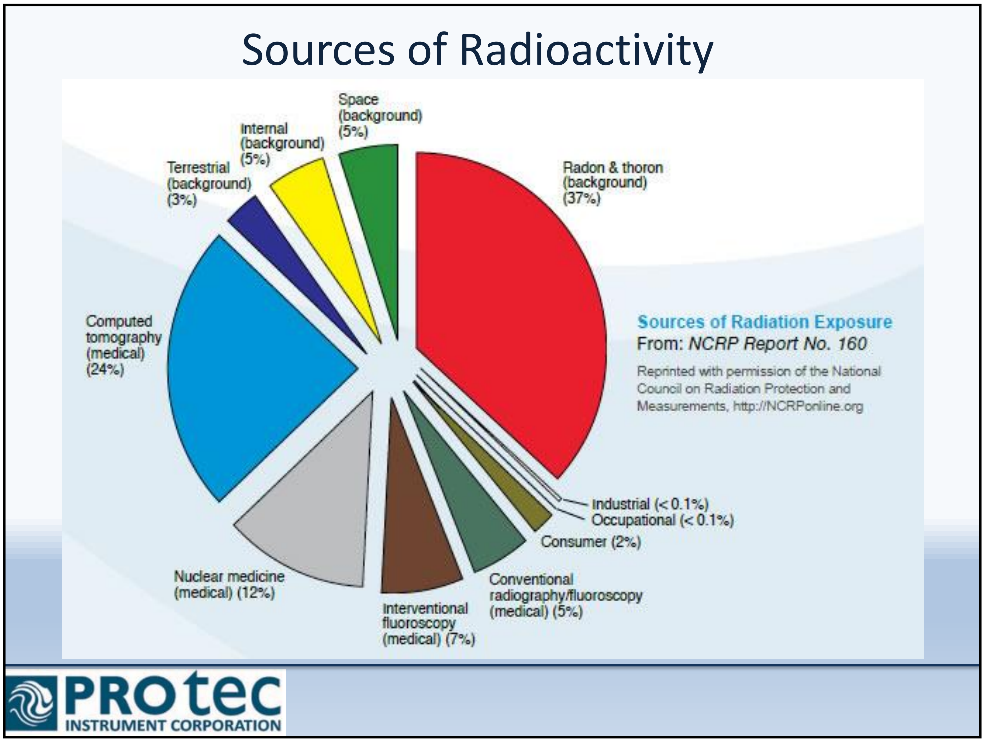
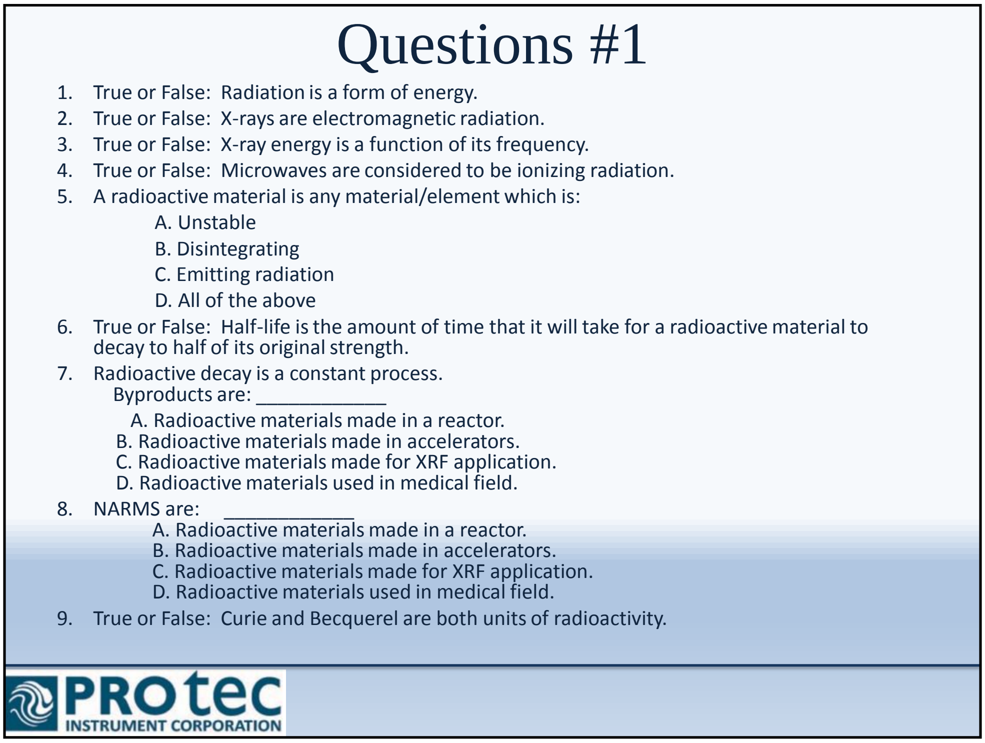
When elements become radioactive or unstable, they automatically attempt to become stable again, and the amount of time that it takes for that to happen varies from one atom to another. Some elements only require a fraction of a second to become stable, and others may take hundreds of thousands of years to become stable. This process has helped to define the term “half-life,” which is defined by the amount of time will it take for a source to lose HALF of its original activity. For example, if a source is releasing an average of ten thousand gamma rays per second, the next half life will be reached when it releases only five thousand gamma rays per second.



Radiation is a part of our world; it always has and always will be. It is part of our natural environment, from materials in the earth, to outer space, and to the foods we eat. The average dose per person from all sources is about 620 mrems per year.

Radiation emissions can be grouped by the sources from which it derives. Different regulations apply to each group, but their effects can be similar.

The majority of radiation exposure in the world comes from the naturally occurring Radon and Thoron, followed closely by exposure to medical radiation, in X-rays, CT scans, etc.

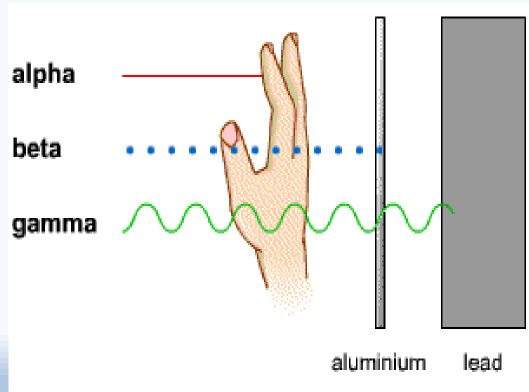


1. True or False: Radiation is a form of energy.
2. True or False: X-rays are electromagnetic radiation.
3. True or False: X-ray energy is a function of its frequency.
4. True or False: Microwaves are considered to be ionizing radiation.
5. A radioactive material is any material/element which is:
   - A. Unstable
   - B. Disintegrating
   - C. Emitting radiation
   - D. All of the above
6. True or False: Half-life is the amount of time that it will take for a radioactive material to decay to half of its original strength.
7. Radioactive decay is a constant process.
   Byproducts are: ____________
   - A. Radioactive materials made in a reactor.
   - B. Radioactive materials made in accelerators.
   - C. Radioactive materials made for XRF application.
   - D. Radioactive materials used in medical field.
8. NARMS are: ____________
   - A. Radioactive materials made in a reactor.
   - B. Radioactive materials made in accelerators.
   - C. Radioactive materials made for XRF application.
   - D. Radioactive materials used in medical field.
9. True or False: Curie and Becquerel are both units of radioactivity.

Exposure Rate and relation to energy

Radiation is energy.

When radiation travels through a material, it deposits energy to that material.



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Radiation is a form of energy. When radiation passes through a medium, such as a body or wall, it fills that medium with radioactive energy. To measure the effects, you must find out how much energy, if any, was absorbed by the material. Different materials, substrates, and body organs, will absorb radioactivity at different dosage rates.

Units of Radiation

RAD (**R**adiation **A**bsorbed **D**ose)

*A unit of **absorbed radiation dose** in material*

Covers any material (tissue, air, water, lead shielding, etc.) and all types of radiation.

1 Rad = 1000 milliRad (mRad)

1 Rad = 0.01 Gray (Gy)

1 Gy = 100 Rad

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The term ‘Rad,’ or “Radiation Absorbed Dose’ is the unit of measure for the dose of radiation absorbed into a material. It is used for any material and all types of radiation, and simply is the product of energy being deposited by radiation.

Units of Radiation

Rem or Sievert (International unit)

A unit used for measuring ***effective dose*** *or the amount of effective biological damage of the radiation.*

1 Rem = 1000 milliRem (mRem)

1 Rem = 0.01 Sievert (Sv) - International

1 Sv = 100 rem

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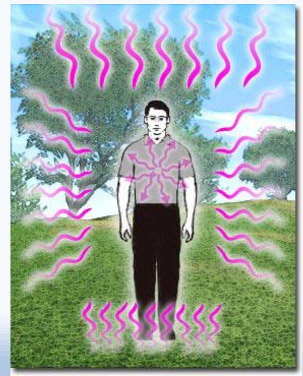
Rem (used in the U.S.) or Sievert (for International) is the unit used to measure a dose of radiation. It measures the amount of biological damage caused by ionization in human body tissue.

Not all radiation has the same biological effect, even for the same amount of absorbed dose.

Radioactivity: Biological affects

Absorbed Dose

- Radiation
  - Q = Quality Factor
  - Q Values:
    - Beta, X-Ray, Gamma = 1
    - Alpha = 10 - 20
    - Neutrons = 2 - 10
  - **REM = RAD x Q (Quality Factor)**
  - Sievert: SI Unit (International Unit)
    - 1 Sv = 100 REM
    - 1 mSv = 100 mrem = 0.1 rem



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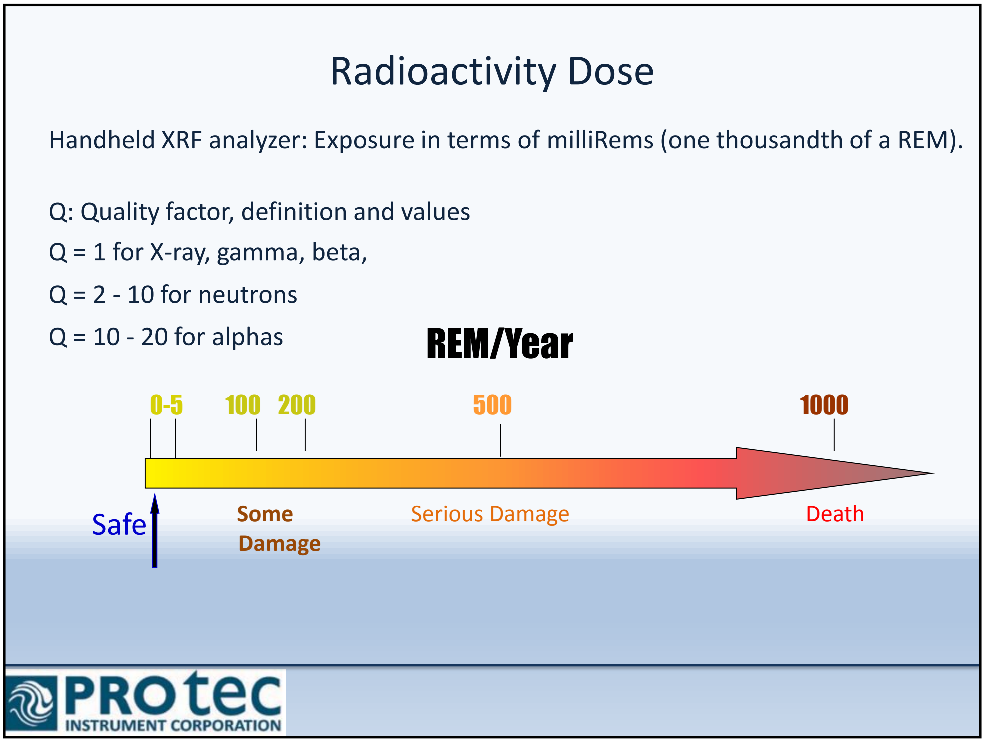
To measure the biological effects of radiation, we need to establish two factors: The unit of measure, and the mechanism of how the radiation impacts the body.

With respect to the biological effect on a human, we use the term dose, or absorbed dose. To measure the amount of absorbed dose per unit mass, the unit used domestically is RAD, and the international (SI) unit is Gray. These units are used when describing energy levels, or absorbed doses, deposited to the body or material.

The different forms of radiation for the same amount of energy can damage the body differently. For example, if a body is hit by X-rays on one side, and neutrons on the other side, and both of them emit the same energy levels, the damage will still vary. To correlate the biological affect to some radiation factor, we use the phrase “Dose Equivalent”, which takes that amount of energy the medium absorbed, and multiplies that by a quality factor, based on the properties of the radioactive source. The unit for that radiation or Dose Equivalent, is an REM. One REM equals 1 RAD x Q and the SI unit, or Sievert, is equal to 100 REM.



In the context of a handheld XRF analyzer, radiation exposure is listed in terms of milliRems, which, again, means one thousandth of a Rem. Radiation dosage, or dose equivalent, can always be rated on a sliding scale. The definition of Rate is an amount of time: Either per hour, per day, per week, or per year, as well as a minimum dosage absorbed per hour, per week, per day, per year, and so on.

Radiation Standards
ICRP, NCRP recommendations

Radiation Safety Standards: Listed in the Code of Federal Regulations (10 CFR), chapters 20, 30, 31, and 32. These regulations govern the safe use of radioactive materials.

Your local state may have additional rules so check with your state's radiation control department.

Radiation Exposure Limits, 10 CFR 20:

	Limits established by NRC	**Limits established by OSHA**
Whole body	5 rem/year (5,000 mrem/year)	1.25 rem/quarter
Extremities	50 rem/year (50,000 mrem/year)	18.75 rem/quarter
Eye	15 rem/year (15,000 mrem/year)	
Fetus	0.5 rem for the gestation period (500 mrem)	

Radiation standards in the USA come from two sources: ICRP- The International Commission of Radiation Protection; and NCRP - The National Council of Radiation Protection.

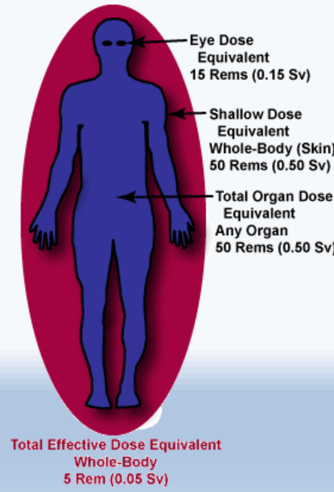
The Code of Federal Regulation, or CFR, details all of the radiation safety standards. To access these in greater detail, see 10 CFR, Section 20.

Your local state may have additional regulations so make sure to check with your state's radiation control department.

Radiation Standards
Annual Exposure Guidelines

Maximum exposure allowances per year:

- *Occupational Exposure = 5 Rem*
- *Individual Members of the Public = 0.1 Rem*
- *General Collective Public = 200 - 375 mRem*
- *Minors (under 18) = 0.5 Rem*



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US regulations categorize the general population into four primary groups, to establish exposure restrictions on annual dosages of radiation:

- Occupational exposure, for those working in a profession involving greater radiation exposure
- Individual members of public
- General public as a whole
- Children under 18 years of age

These exposure levels are the maximum permissible dose for whole body exposure.

Radiation Standards

Average Annual Occupational Doses*

Occupation	mSv	mRem
Airline flight crew member	10	1000
Nuclear power plant worker	7	700
Grand central station worker	1.2	120
Medical personnel	0.7	70
DOE/ DOE contractors	0.44	44

* Based on U.S. data only

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Annual exposure varies among the many occupational contexts where radioactivity is present, depending on the nature of the job.

Occupational exposure is closely monitored, and allowable exposure can vary for different parts of the body, as each organ contains a different rate of absorption.

And because there are no organs within our extremities, maximum allowed dose levels in the extremities of, for instance, an airline flight crew member, can be up to 50 Rem per year.

Radiation Standards
General Exposure

Source	µSv	mRem
Cigarette smoking	8000	800
Radon in homes	2000	200
Medical exposures	530	53
Terrestrial radiation	300	30
Cosmic radiation	300	30
Round trip US by air	50	5
Building materials	36	3.6
World wide fallout	<10	< 1
Natural gas range	2	0.2
Smoke detectors	0.001	0.0001

On average, a typical person receives 0.62 Rem (620 milliRem) of exposure per year, from natural and manmade sources.

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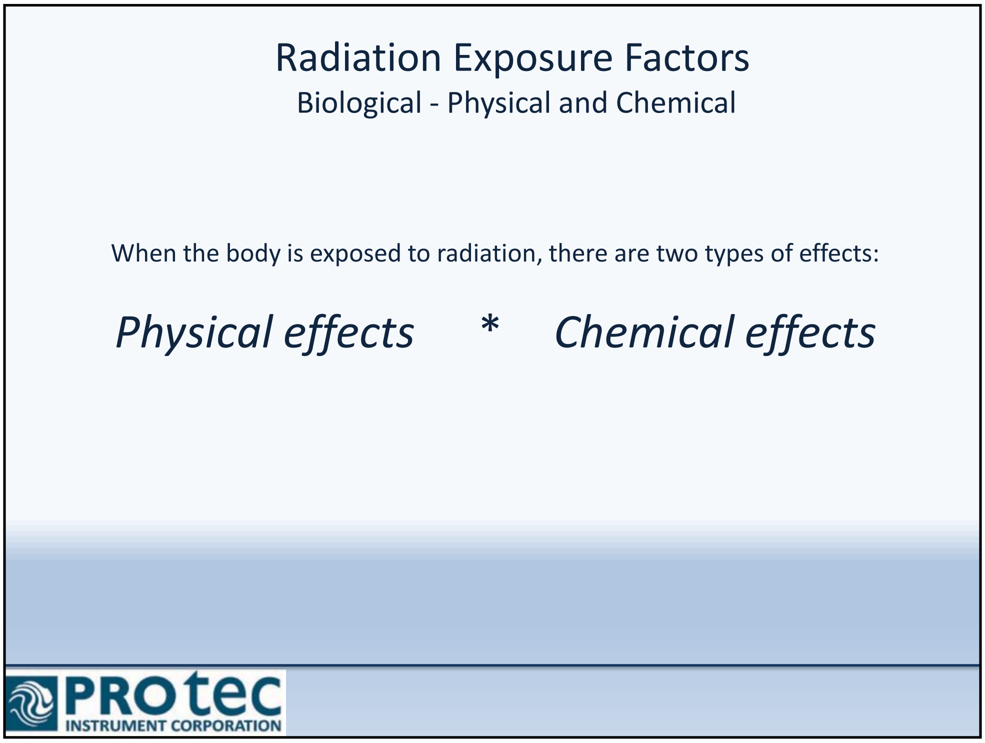
By living on earth, exposure to radiation in various forms is inevitable.

The average US resident is exposed to approximately 620 milliRem per year. Your exact geographic location can also greatly affect the levels of radiation that you ingest. For example, living in Albuquerque, NM, which is 4,900 feet above sea level, residents experience greater exposure to UV rays than those living at sea level. Meanwhile, radiation exposure from radon in the ground is present virtually everywhere, albeit in minute quantities. Even our own bodies make radioactive material, for example Potassium 40 is biologically generated.

Medical X-rays typically cause 25 to 55 milliRem, depending on the procedure. Flying in a jet airplane at 30,000 feet exposes one to approximately 0.5 milliRem per hour. Also, tobacco is naturally a radioactive material. Smoking a pack and a half of cigarettes a day puts approximately 8,000 milliRem of radioactivity into your lung tissue.

Radiation is part of our daily lives- it cannot be avoided. You must understand it and respect it, especially if you work with it.



There are two types of effects when the body is exposed to radiation; physical and chemical.

The physical effect is the ionization of the atoms in tissue cells, which will typically cause those cells to die, if the damage is too severe. If a cell is not severely damaged, it might be able to repair itself and continue functioning, but could lose its ability to divide. This is known as reproductive cell death. The third cellular change that might occur is mutation of the damaged normal cell into a carcinogenic cell, which may cause cancer.

The chemical effect from exposure to radiation is the breakdown of the molecules and the chemistry in our body. For example, our body is composed mostly of water, or H20, which can break down into ions – OH and H, negative and positive. These eventually are free-radicals and then can turn into H202, or hydrogen peroxide. Hydrogen peroxide is not natural, and ideally should not be present. Lead could tag along with one of these and become lead oxide. Typically, the body can successfully reject what it doesn't need. However, when atoms oxidize, they generally stay; and to get rid of them, the chemistry must be broken. The chemical process used in breaking down the bonds to remove hazardous elements, or heavy metals out of ones body, is known as the chelation process.

Just as every human is unique from one another, so, too, is the susceptibility of every individual to radiation. If we were all exposed to radiation, the effect will often depend on our genetics, our way of life, what we eat and where we live, as well as our surroundings.

Radiation Exposure

Biological Effects: Short-term vs. Long-term

Short term effects:

– Nausea, diarrhea, and reddening of the skin.

Long term effects:

– Weakened immune system, loss of hair, and even increased chance of cancer.

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Radiation exposure is categorized as short- or long-term. Short-term effects are nausea, diarrhea, and reddening of the skin. Long-term effects include a weakened immune system, loss of hair, and often an increased risk of cancer.

These effects are only apparent at extremely high doses (500 Rem and above), caused by the radiation depositing energy into a cell's DNA, requiring the cells to stop and repair themselves, or the cell will die. In rare cases, the cell will repair itself incorrectly, which can lead to cancer.

Radiation Exposure Factors

The ALARA Concept: The Golden Rule

As
Low
As
Reasonably
Achievable

3 basic practices to maintain ALARA:

Time – *Reduce the amount of time spent near a source of radiation.*

Distance – *Stay as far away from the source as possible.*

Shielding – *Place correct shielding between workers and the source.*

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ALARA is an acronym for “As Low As Reasonable Achievable”. It is the golden rule, when in the presence of radioactivity. The ALARA concept means that, under all conditions, one should reduce exposure to radiation whenever possible, regardless of the amount of radiation present. The ALARA concept is the foundation of radiation safety.

When working with radiation, one should ask, “What type of radiation am I working with, and what is the activity level of that radiation? What is my dose if I operate the XRF device under normal working conditions? And what does the XRF device do if something happens to it under accidental conditions?

Because accidents can happen, it is important to note that the levels of radiation contained in a handheld XRF device will be in a matter of milliRems per year, far below the levels of what the government has set as maximum permissible dose.

Radiation Exposure Factors

ALARA: Time, Distance, and Shielding

TIME: It is best to reduce the amount of time spent near a source of radiation.

Example:

	XRF Device #1	XRF Device #2
Activity Level	2.0 mRem	0.2 mRem
Time to measurement	2 seconds	100 seconds

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The first factor we will look at, Time is a linear factor. For example, if I have two XRF Devices – Device #1 puts out 2 mRem, and Device #2 puts out 0.2 mRem. Judging only by these two figures on their own, which machine would you want to use? XRF Device #2 seems like the lowest exposure, however… Then consider that Device #1 only takes two seconds to obtain a reading, and #2 takes 100 seconds. This discrepancy affects the equation, since the exposure time is much longer with Device #2.

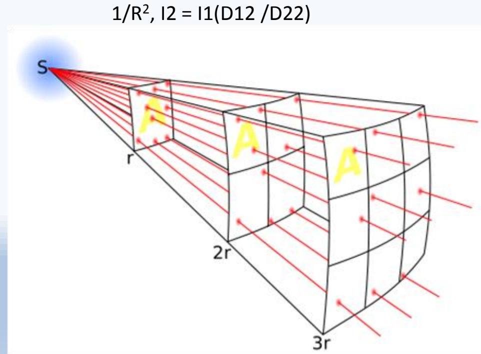
Radiation Exposure Factors

ALARA: Time, Distance and Shielding

Distance – It is best to stay as far away from the source as possible.

Radiation exposure from a source follows the inverse square law. The further you are from the source the less radiation you are exposed to. For example, if you double the distance between you and the source you will reduce your exposure to 1/4 the original value.

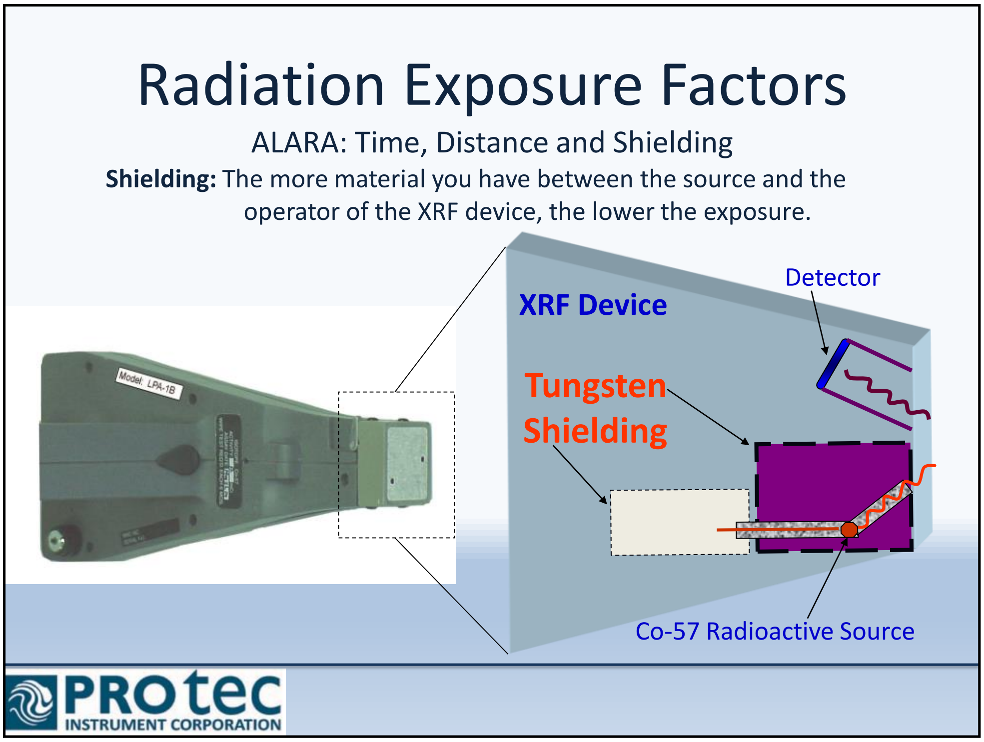
$1/R^2$, $I2 = I1(D12 /D22)$



Distance is the most important factor in the ALARA concept. Exposure, with regard to distance, uses the inverse square law or $1/R^2$, where ‘R’ is the distance from the source.

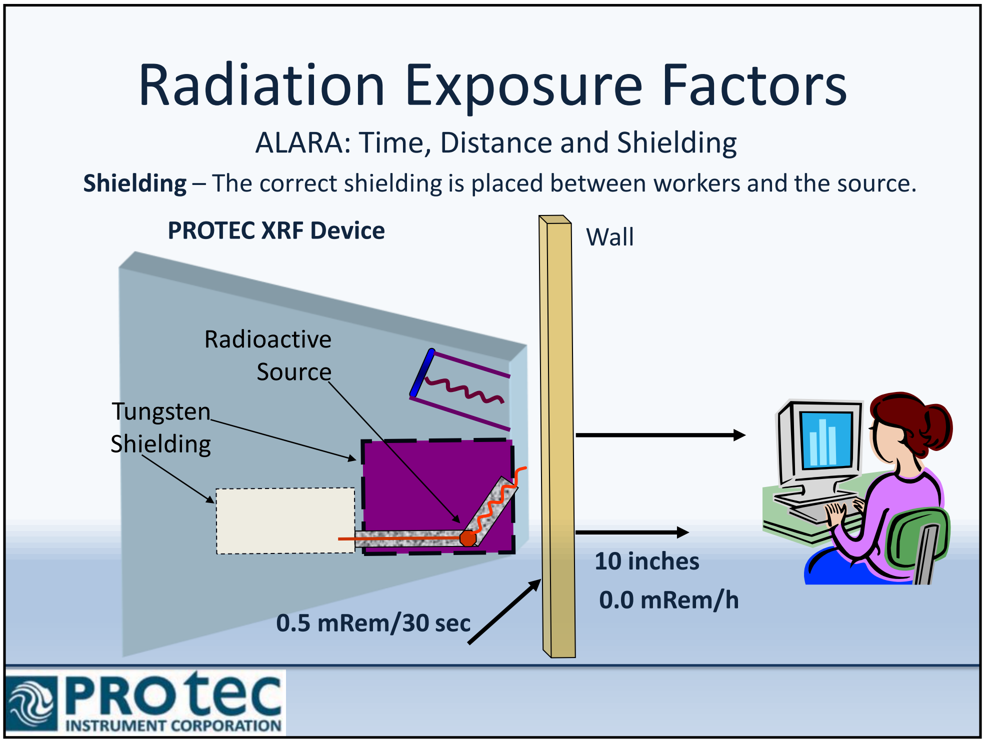
For example, say I have a source that releases 10,000 gamma rays. If I move from distance r to 2r, say r is two inches away from the source and 2r is ten inches away. If I’m measuring 10,000 gamma rays at r, divided by a square of the distance of 2 inches, is 2,500 gamma rays. And then I move to 2r, I am measuring 10,000 by a square of the distance or 10 inches, which is 100 gamma rays. This means that if I increase my distance by a factor of five to one, my radiation exposure drops by a factor of 25 to one.

Because distance is such a crucial factor to radiation safety, this concept should be applied when using your XRF device. You would not want to hold the instrument against your body, or sit on the case when taking a break, etc.



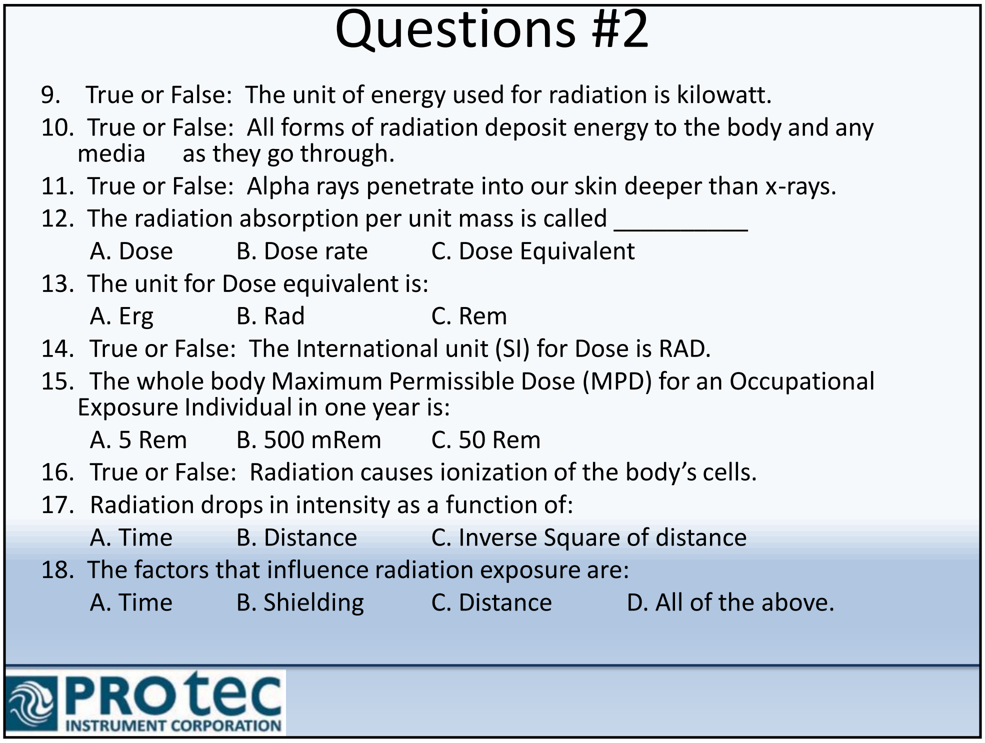
In the context of the XRF device, shielding is just what it sounds like – the material that shields, or blocks, the radioactive emissions from a source from traveling in a certain direction.

The higher the density of the shielding material, the more effective it will be in containing gamma rays. In PROTEC's XRF devices, the radioactive sources are very small and are contained within a tungsten fixture. This fixture is the heaviest available and has excellent mechanical integrity, along with strong radiation absorption. The source is exposed only when the housing mechanism rotates and slides open during a reading and is effectively shielded when the system is not taking a reading.



As you can see from this diagram of the PROTEC XRF device, the amount of exposure in this case is affected by time, distance, and shielding. The source is contained in its tungsten housing and is blocked by the wall on which it is taking a reading. These shielding factors, coupled with the distance of a mere 10 or more inches, will result in minimal exposure to someone on the other side of the wall, even if the reading time were to take as long as 30 seconds. Since the PROTEC XRF devices will typically take a reading in less than 5 seconds, the exposure is negligible at best.

Taking into consideration the average read time, shielding and distance, the normal dose at the inspector’s hand is 0.3 mRem per hour and at the torso level, it is approximately 0.0 mRem, based on the systems SS&D document.



9. True or False: The unit of energy used for radiation is kilowatt.

10. True or False: All forms of radiation deposit energy to the body and any media as they go through.

11. True or False: Alpha rays penetrate into our skin deeper than x-rays.

12. The radiation absorption per unit mass is called __________

A. Dose B. Dose rate C. Dose Equivalent

13. The unit for Dose equivalent is:

A. Erg B. Rad C. Rem

14. True or False: The International unit (SI) for Dose is RAD.

15. The whole body Maximum Permissible Dose (MPD) for an Occupational Exposure Individual in one year is:

A. 5 Rem B. 500 mRem C. 50 Rem

16. True or False: Radiation causes ionization of the body's cells.

17. Radiation drops in intensity as a function of:

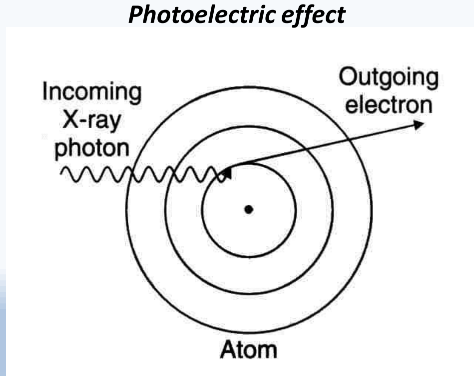
A. Time B. Distance C. Inverse Square of distance

18. The factors that influence radiation exposure are:

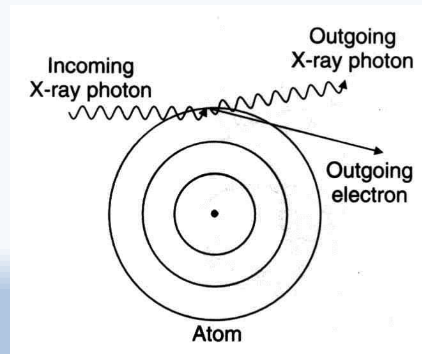
A. Time B. Shielding C. Distance D. All of the above.

Interaction of Radiation with Matter: Photon Interaction with Atomic Electrons

Photoelectric effect



Compton effect



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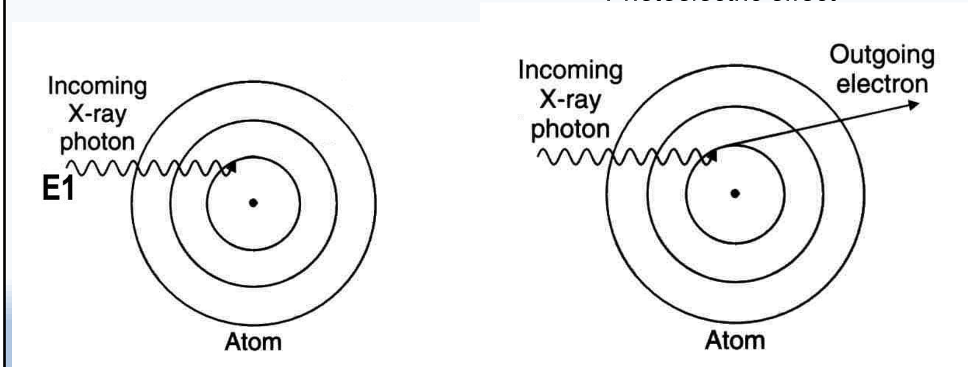
When radiation interacts with an atom, it is referred to as photon interaction. Photons, gamma rays, and X-rays interact with the elements in three ways: Photoelectric effect, Compton effect and Pair Production. X-rays are coming from the XRF device, and they come in contact with the atom. When radiation interacts with an atom, a specific amount of energy is required to remove an electron from that atom.

Today we’re taking a closer look at the Photoelectric Effect and the Compton Effect.

Interaction of Radiation with Matter: The Photoelectric Effect

Photoelectric effect



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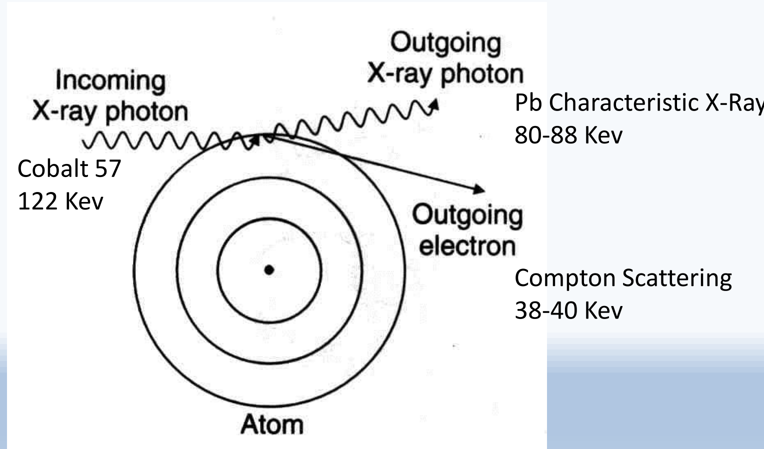
If the energy, E1, is less than the binding energy of that electron, it is not affected. The atom absorbs the energy.

The next scenario is when the energy is equal to, or slightly higher than, the binding energy; This is the photoelectric effect. The atom absorbs the radiation, and an electron gets ejected.

Interaction of Radiation with Matter: The Compton Effect, Scattering



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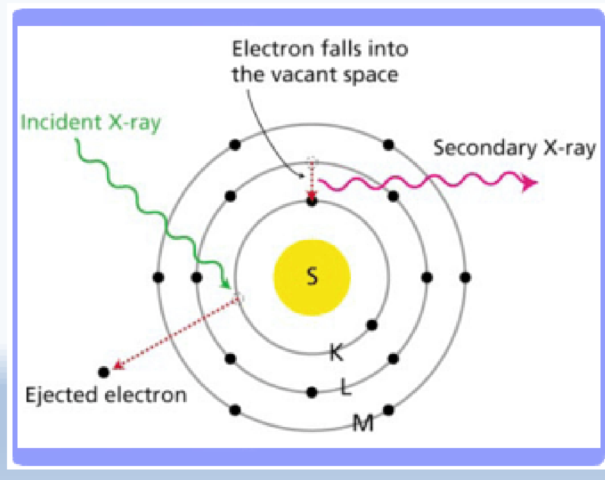
When the energy of the incoming photon is much higher than the binding energy of the atom, the effect is similar to the photoelectric effect, in that an electron is ejected; the issue is that there is some energy remaining.

For Example, let’s look at a Cobalt-57 source with 122 Kev energy, the binding energy if this is a lead atom, is around 80 to 88 Kev. Therefore there is about 38-40 Kev energy remaining. The remaining energy continues in a different direction, at a different angle. This is the Compton Effect, also known as Compton scatter. This comes into play as a dominant factor in this type of XRF.

Interaction of Radiation with Matter: Characteristic X-Rays



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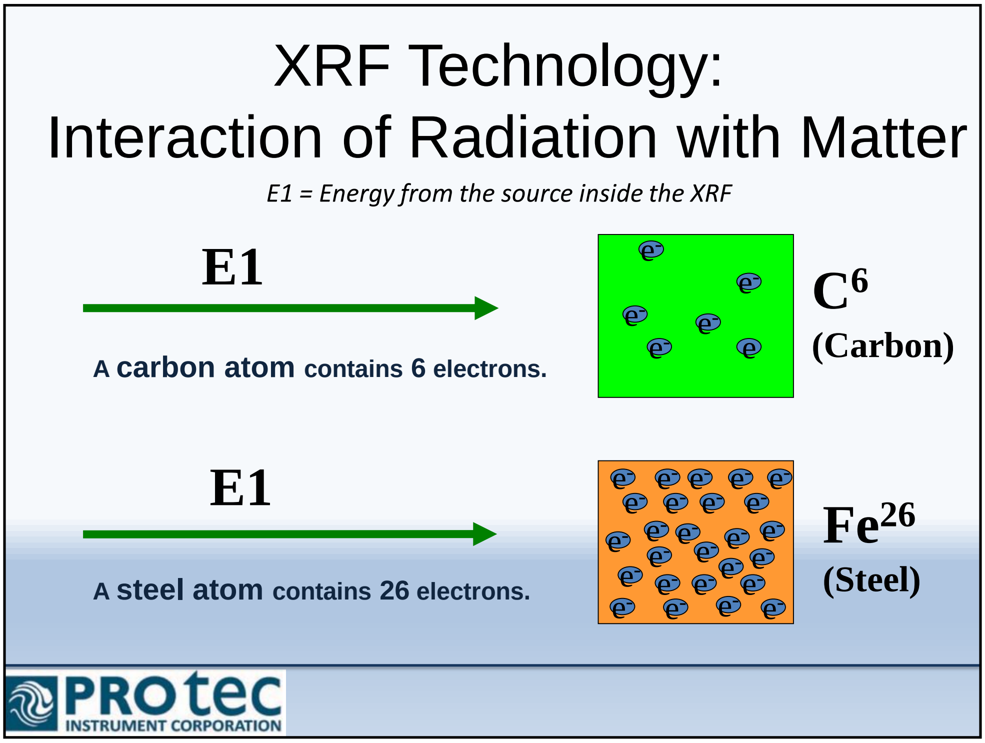
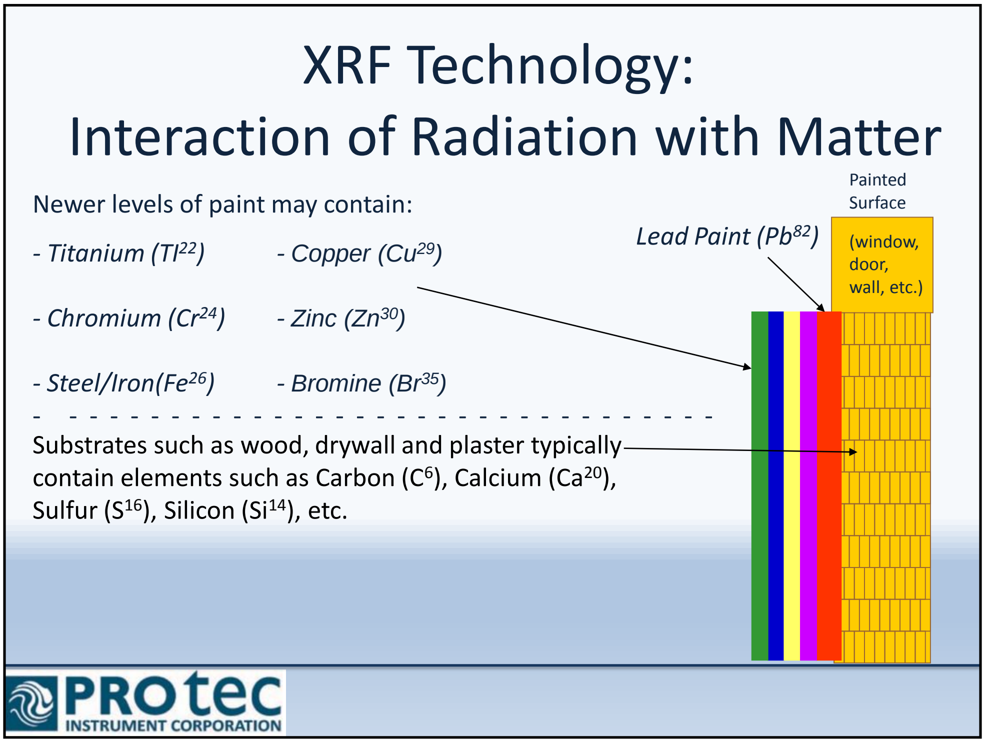
When energy from a source affects an atom such that an electron is ejected, the atom must adjust by allowing another electron from another shell to take it's place. Since the electrons are transitioning from one energy level to another, the energy discrepancy among the two has to be adjusted. The atom charges itself to get rid of that energy and sends out an X-ray, in this case, known as a "characteristic X-ray" photon. The characteristic x-ray photon has an energy that corresponds exactly to the difference in energy between the energy level that is vacant and the energy level from which an electron ejects. The x-ray energy is characteristic of the atom that had the vacancy and can be used to identify the atom and is equal to the binding energy of the two electrons which have changed places.

Every element has its own unique set of characteristic x-rays. These characteristic X-rays are X Ray Fluorescence, or XRF. If it comes from the ejection of the K-shell electron, it is K-shell XRF. This concept is the foundation of XRF generation.



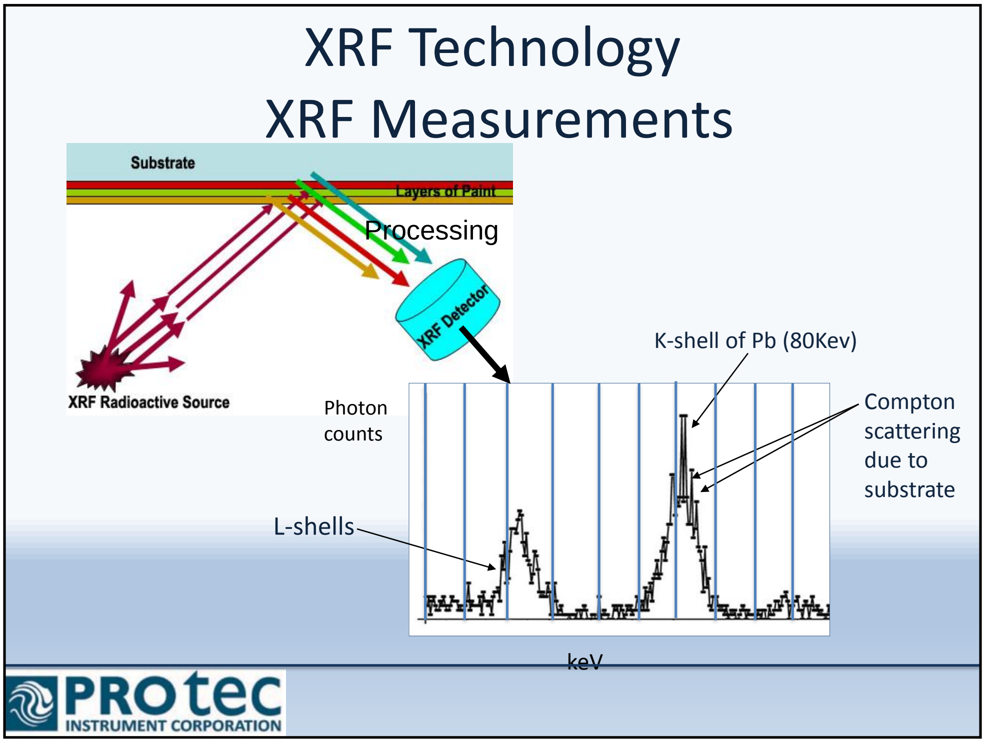
When radiation from the source inside an XRF device hits an atom during a reading, it does not matter what type of atom is in the substrate; the gamma X-rays will react, but their electron count determines the extent of their reaction. For example, let's look at two elements that are commonly found in building materials: Carbon, which has 6 electrons; and steel, which has 26 electrons. If both of these atoms come in contact with the radiation in the source used by our XRF, the radiation will penetrate the carbon atom more easily, because it has fewer electrons.

This is why dentists use lead aprons for X-rays, rather than stainless steel -- Lead has 82 electrons, while steel has only 26. Having more electrons, lead atoms can block more radioactivity. To break it down, radiation absorption for X-rays and gamma rays is a function of atomic density. The more dense the atom, the more radiation it can block.



Since lead paint has not been used in construction for several decades, it's likely to have been covered by multiple layers of paint, since the time when lead was still allowed. These other layers could contain other elements such as titanium, chromium, steel, copper, zinc, bromine, etc. Therefore in order for the radiation from the XRF device to penetrate to the layer of lead paint and back to the unit's detector, it will require a higher amount of energy.

Lead is the heaviest of all elements used in any paint or substrate. The PROTEC XRF device will process the characteristic X-rays of all the elements present, specifically screening for the characteristic energy of lead. Since, in some cases, lead is three times more dense than any of the surrounding elements, it's characteristic energy is higher than its surroundings, and therefore, more effectively measured.



Here, we'll take a look at how all XRF devices process measurements, and what actually happens when radiation interacts with the detector.

As radiation comes in contact with the detector, the device attempts to determine how many photons entered, and at what energy levels.

For example, if 20 photons come in at 15 keV, the device charts it and records it; if 500 photons come in at 80 keV, that is also recorded. If 100 photons come in at 67 keV, as this figure is not divisible by 5, the device is designed to perform averaging, by recording half of the photons at 65 Kev and the other half at 70.

Sometimes, too many energy pulses will try to enter at once, so if 100 pulses enter at 25 keV, and they all cannot be recorded, this is referred to as "saturation pulse pile-up," when the pulses come in faster than the electronics can accommodate. When the device has finished collecting all of the pulses, and the reading is complete, the result is a spectrum, or a graphic representation of all events that took place inside the detector.

Each of the peaks and valleys help to determine the reading. These first peaks here are lead L-shells. Lead's peak is around 80 keV. The two bumps are the Compton effect, which are caused by scatter picked up in the substrates. If the substrate is metal, those Comptons can be larger than the peak from lead. So when you want to separate scatter on a metal substrate from the direct counts from lead, it takes time to make the distinction.

All XRF devices use either K-shell or L-shell energy, to determine whether lead is present both of which has its own advantages and disadvantages.

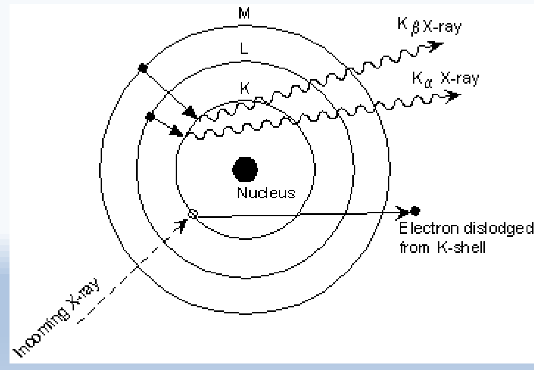
XRF Technology:

K-shell vs. L-shell XRF Analysis

K-shell X-rays = 88 keV

L-shell X-rays = 15.87, 15.21, and 13.04 keV

HUD and EPA favor K-shell analysis for multiple reasons



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An XRF device using K-shell analysis requires substrate correction, either manually or automatically, but with the PROTEC LPA-1 this is done automatically.

One advantage of K-shell analysis is high energy readings, which provide better penetrating power than L-Shell. If there are multiple layers of paint, even if they're characterized by a heavy charge, the device will still penetrate through to the lead paint, and the signal is less likely to be absorbed by the other layers of paint. Since the XRF device emits high energy levels, the atoms in its pathway cannot stop it as easily. There is no element in paint with a similar kind of X-rays, or energies, to that of lead. The two elements surrounding lead on the periodic table are mercury and bismuth. Bismuth is not used in paint, and mercury is mostly volatile.

But high energy K-shell technology can also have its disadvantages; Some of the older lead detection devices will be powerful enough to locate lead on the *opposite* side of a door or wall, or even lead pipes *within* the wall. The PROTEC XRF devices have a mechanical solution to prevent this over-sensitivity; The tip of the device sends the radioactive signal out and subsequently receives it at an angle, which allows the depth of penetration to be controlled. By adjusting the angle, the level of penetration can extend either deeper or shallower into the substrate. The other disadvantage of higher energy K-shell readings, is the Compton Effect, or the scattering of photons in matter, resulting in a decrease in energy or gamma ray photon. The discrepancy in energy levels within the substrate must also be accounted for, in order to achieve an accurate reading, which, in the case of the PROTEC XRF devices, is automatically done.

HUD Chapter 7, along with the EPA's methodology for the Performance Characteristic Sheet (PCS), clearly indicate the effectiveness of K-shell X-rays for lead in paint measurements, warning against the reliance on L-shell measurements -- Due to their low energy, penetration only goes as deep as a surface measurement, as elements in the paint will absorb the weaker energy. This, in turn, can increase the risk of false negatives.

Another disadvantage of L-shell technology is the matrix effect, whereby if the paint contains Cobalt, Zinc, Arsenic, or Selenium, it will show X-rays that are very close to lead, and thus could yield a false positive result, leaving the inspector to make a judgment call as to the results, which, in turn, adds to the time and liability.

The advantage of L-shell technology, however, is low Compton scatter, meaning there is no need to follow up with substrate correction.

XRF Technology:

Advantages of XRF Analysis

Non-Destructive

The painted surface does not need to be disturbed to obtain a measurement.

Portable

Handheld device

Fast

Immediate results

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Today's XRF devices are light-weight and hand held.

The benefits of XRF technology for the detection of lead in paint, is that it can take a quantitative measurement very quickly, without disturbing the surface in question.

Alternative methods involve removing a paint chip and sending it to a lab, or scraping the surface to conduct a chemical test.

Dosimetry: Measurement & Calculation of absorbed dose in a Medium

Active Methods

Active methods for dosimetry assessment include devices such as Geiger tubes, ionization chambers, etc.

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In order to measure radiation, you have to interact with it, in one way or another. When radiation from an XRF analyzer makes contact with a surface, it deposits energy, causing the electrons to eject. This is the energy we're measuring with XRF technology. There are two methods used in radiation measurements – active and passive, and each method has advantages and disadvantages.

Active methods include pieces of instrumentation such as Geiger tubes, which detect a single particle of ionizing radiation and display it with an audible effect. The probe pictured here contains a gas current, whereby a radioactive signal ionizes the gas simply by touching it. By adding voltage, the electrons will move, and when the electrons move, it will read a volt, moving the needle indicator. This is an effective method, because it actively and instantly reads the source and quantity of radiation.

One of the disadvantages of this device is that it cannot measure all forms of radiation; different devices are required for different types of radiation. Another example would be the neutron radiation meter. Because there's no way to stop a fast neutron, you can only slow it down in a device, with hydrogen, and either water, plastic, or wax.

There are passive methods to measure radiation such as film badges, TLD's, etc. These are referred to as 'passive' because the measurement is not readily available. These are worn on an article of clothing or a hand or wrist, and after a set period of time, a report will be generated, indicating a persons level of exposure. The obvious advantage is portability and flexibility, as these can be worn and forgotten about on a daily basis.

The disadvantage is that the film badge does not protect you from radiation; it simply indicates that the portion of your body where you were wearing the badge, was affected by radioactivity. Another disadvantage is that the badge will not detect radiation exposure on the waist of someone wearing the badge on his chest, if radiation exposure only happened at the waist.

The lab calculates full body exposure, using an algorithm, so, in another scenario, if a fine beam of radiation were to hit the badge directly, when the dosimeter is later evaluated at the lab, the results would be inaccurate. In this case, the results on the badge may come back and reflect a very high level of exposure, even though that was not necessarily the case.

Overall, these dosimeter badges are very sensitive. Therefore, they should not be left where they can receive intense solar exposure, such as on the dashboard of a car, or on top of an old TV or microwave oven, as the badge cannot distinguish between radiation from a TV or that from an XRF device. When the badge is not in use, it should be put in a place in which the possibility of exposure to radiation is at a minimum.

Please recognize that this is to show how much radiation you, as an inspector, receive, so the badges should not be kept inside the XRF case. As an XRF manufacturer, we recommend the use of dosimeter badges for many reasons, even though the LPA-1 is not capable of a dosage higher than 10% of the maximum permissible dose allowed by federal law. So, technically, you are exempt from the necessity to wear these, yet these are necessary for liability reasons. Since your hand is the closest area to the source of radiation, use a ring badge or place the clothing badge on your wrist, at your sleeve. Essentially, it should be worn in the area where you think you have the highest possibility of exposure.

Dosimetry:

Comparison of Active vs. Passive Methods

	Active	Passive
Pro	• Get results instantly • Can be used whenever a measurement is needed • Good in unknown situations	• No need to take measurements, because the device is automatic • Inexpensive • Used for legal records • Easy to carry around
Con	• Requires time and money to use and obtain equipment • Not accepted for legal record	• Takes time to get the final results • Needs to be worn all of the time

The low levels given off by the PROTEC XRF device does not warrant the use of a direct measuring device. Since there is some exposure from the device, due to the nature of XRF lead analysis. It is recommended that passive monitoring is used from an approved vendor.

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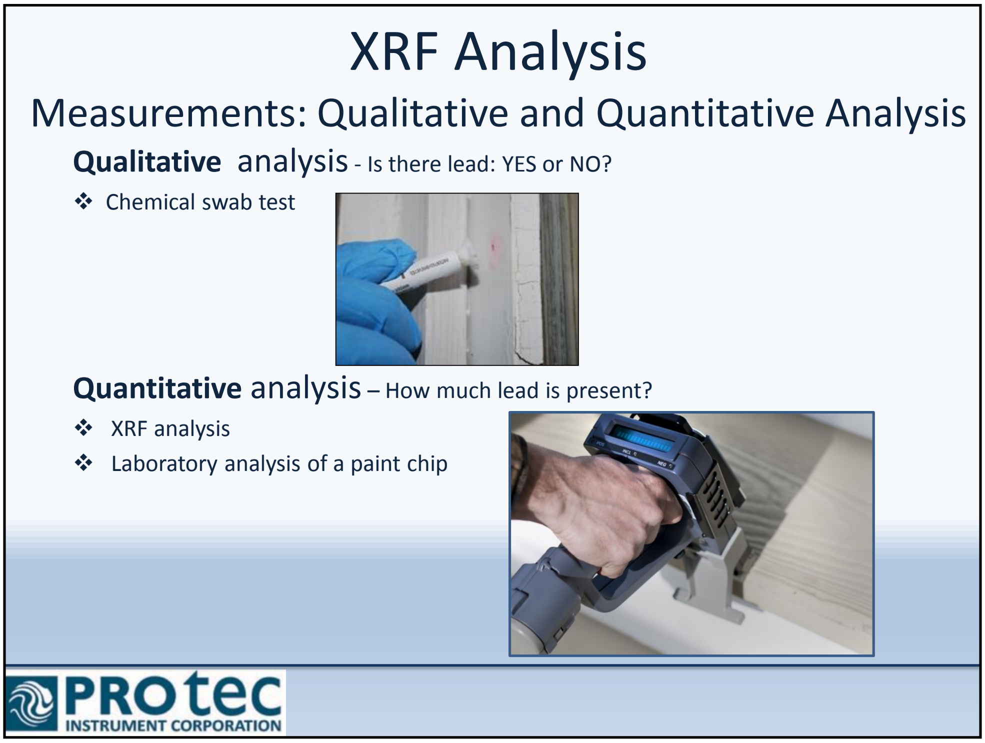
Here is a comparison of the two methods of dosimetry:

While Active methods give results instantly, can be used whenever a measurement is taken, and are the method to use in unknown situations, they also requires time and money to obtain, and are not accepted for use in legal records.

Pro’s for Passive dosimetry methods are that they do not need to be activated in order to initiate a reading, they are typically inexpensive, they can be used for legal records, and it is more lightweight and portable than active methods. However, the results are not instant, and the devices or badges need to be worn consistently, in order for results to be accurate.

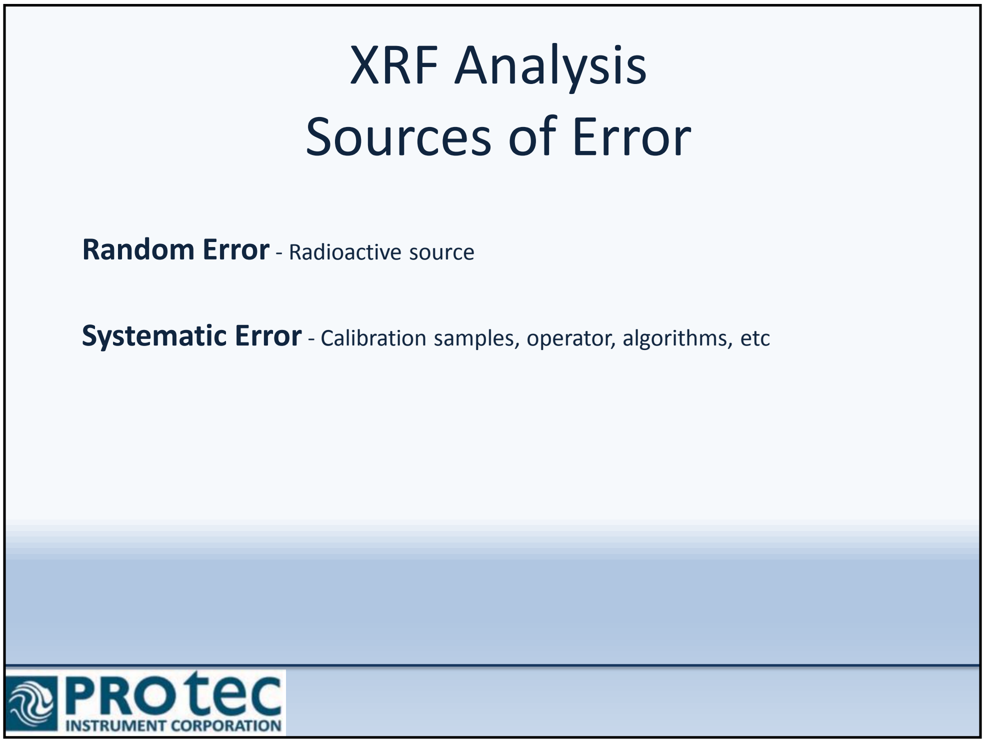


XRF technology requires a set of standards in order to calibrate the system, and NIST standards are the only acceptable standards, according to HUD regulations. However, there is no set of standards for every surface of paint. NIST standards are clean-textured paint samples. Therefore if an inspector is testing in a location containing corrugated surfaces, as well as textured surfaces, the best he can do is estimate. He should not try to compensate for the limitation of XRF technique, which is the lack of standard for every single surface and substrate.

There are two type of measurements: qualitative or quantitative.

Qualitative readings provide a yes or no, or positive or negative result. An example of a qualitative test is a swab test.

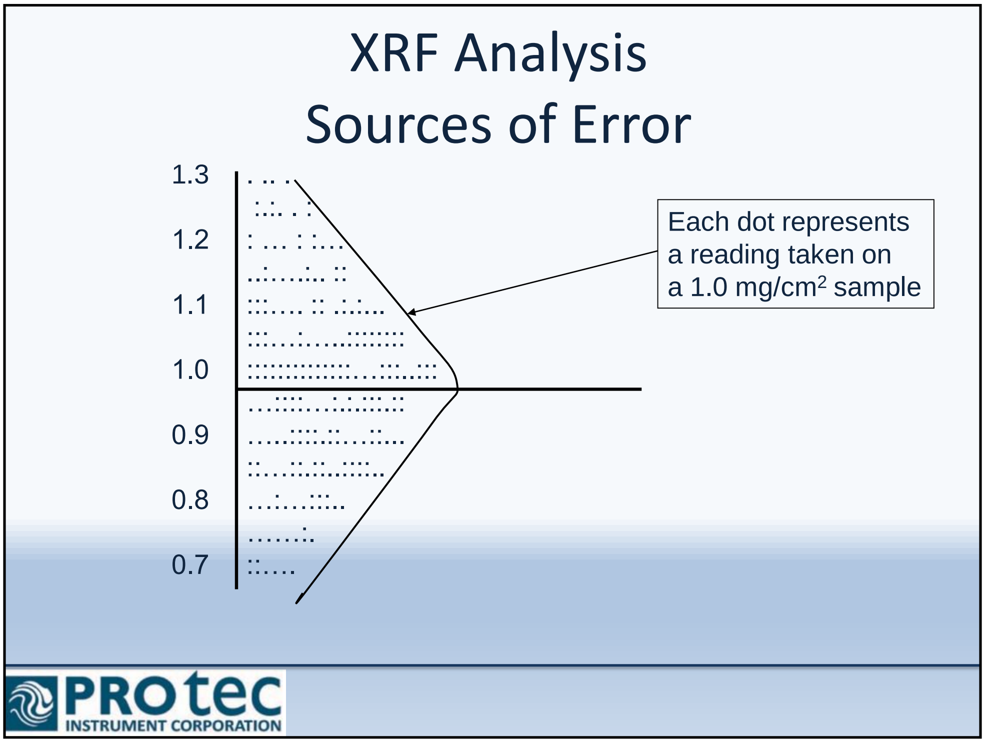
Quantitative readings provide results in the form of a number. These are required when following the HUD Title 10 requirements. A lead inspector is looking to determine a condition as being either positive or negative, as it relates to some action level with some degree of certainty.



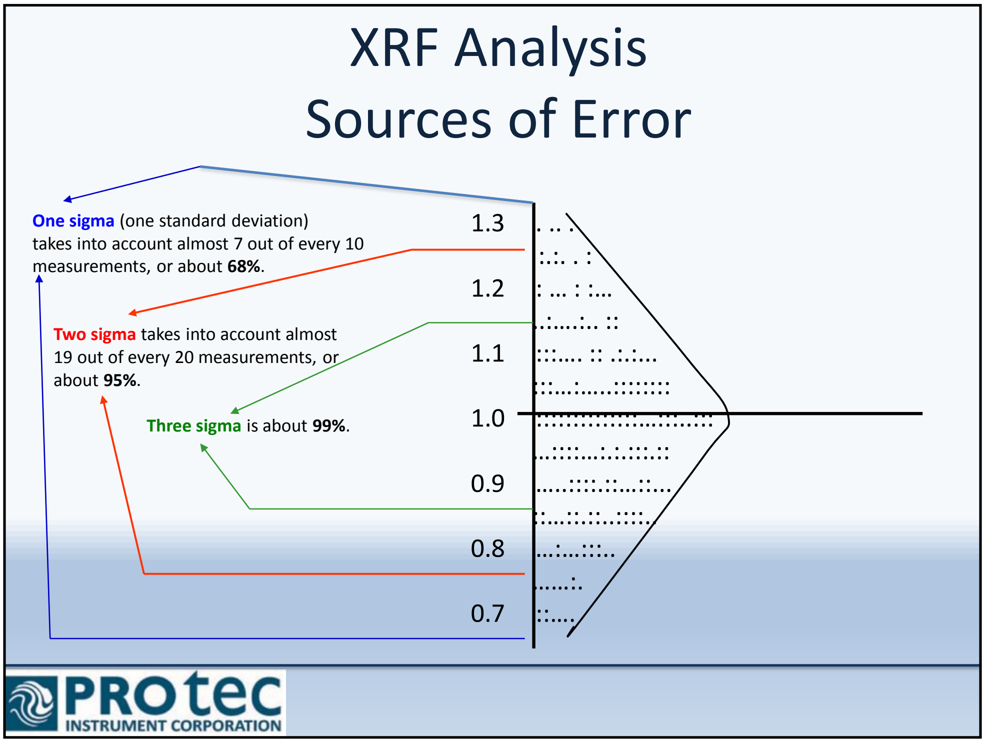
When taking a reading, there are two types of error:

- Random
- Systematic

When you combine the random error and the systematic error, you get your confidence level or total level of uncertainty.



The LPA-1 takes readings in an area-density unit, specifically milligrams per centimeter squared. To determine the confidence level, let us use a 1.0 mg/cm2 and repeat a reading 100 times. Results will be distributed throughout a spectrum surrounding the value of that sample, known as sigma, or in this case 1 mg/cm2.



The term ‘one sigma,’ or one standard deviation, refers to an imaginary line that surrounds the *whole average value*, which takes into account almost 7 out of every 10 measurements taken, or about 68%. It is the point where 68% of the measurements would fall around the average value. Two sigma is that imaginary region that includes 19 out of every 20 measurements, or 95%. And three sigma is 99% of where these measurements will fall.

The HUD guidelines specify that every measurement should achieve a 95% confidence level, or be within two sigma. Two sigma is a value equating to plus or minus some other value, which is a function of time, substrate, and the amount of lead present. By measuring for a longer time, random error is reduced. Wood is a more accurate substrate for taking a reading than steel. And if lead content is 5%, it’s easier to measure than 0.5% lead.

XRF Analysis Statistics

To understand the fundamentals of XRF analysis, requires statistics. There are four primary terms:

- Precision
- Accuracy
- Bias
- Uncertainty, or confidence

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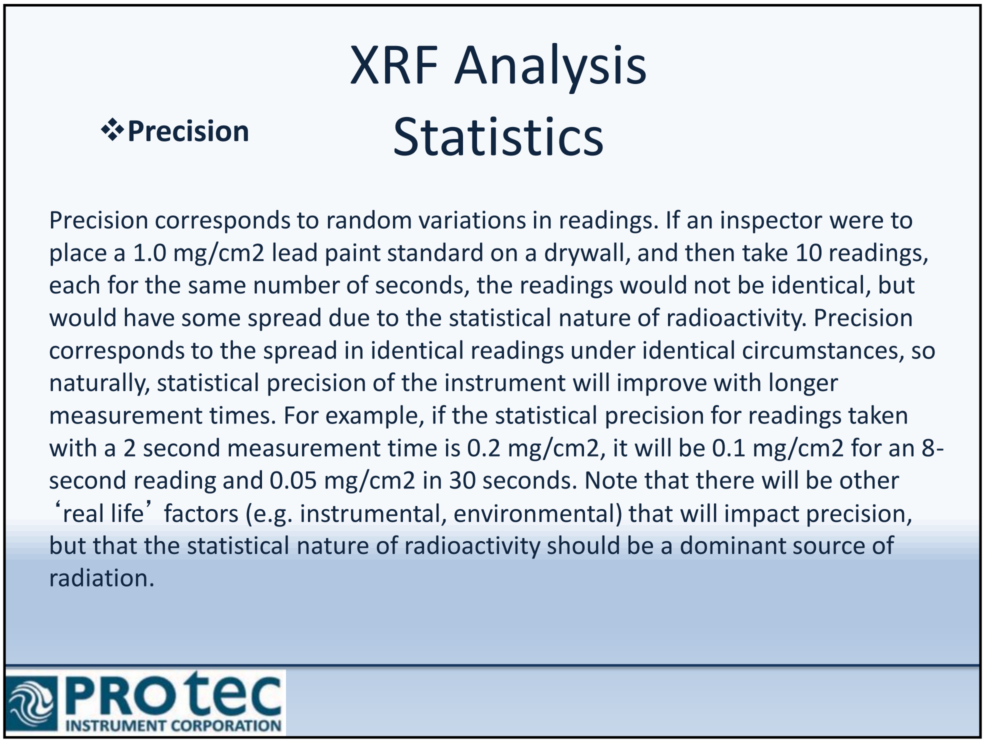
To understand XRF terminology, requires statistics. There are four terms that need to be understood :

- Precision,
- Accuracy,
- Bias
- And Uncertainty, or confidence.



The first term, precision, corresponds to random variations in readings. If an inspector were to place a 1 mg/cm2 lead paint standard on a drywall, and then take 10 readings, each for the same number of seconds, the readings would not be identical, but would have some spread, due to the statistical nature of radioactivity. Precision corresponds to the spread in identical readings under identical circumstances, so naturally, statistical precision of the instrument will improve with longer measurement times. For example, if the statistical precision for readings taken with a 2 second measurement time is 0.2 mg/cm2, it will be 0.1 mg/cm2 for an 8-second reading and 0.05 mg/cm2 in 30 seconds. Note that there will be other 'real life' factors (e.g. instrumental, environmental, etc.) that will impact precision, but that the statistical nature of radioactivity should be a dominant source of radiation.

XRF Analysis Statistics

❖ **Accuracy**

Accuracy is used in evaluating the performance of a lead paint analyzer. Ideally, if you were to take a large number of readings on a 1.0 mg/cm2 standard sample, the average value of those readings would be 1.0 mg/ cm2. In the real world, the average would probably be a value somewhat different, such as 0.95 mg/ cm2. This difference between the average measured value of the lead content of a paint sample and its actual value is called the Accuracy, and cannot be corrected by taking additional measurements.

For example, if an inspector were to measure the 1.0 mg/ cm2 standard on a large number of pieces of drywall - each piece would produce its own average. There would be variation in the individual averages, due to small systematic errors present in any instrumentation. The variations in the average readings is fixed for a given XRF analyzer.

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XRF Analysis Statistics

❖**Bias**

For the LPA-1, the biases that may be present with most common building material substrates have been measured to be virtually zero. This means that the instrument automatically corrects measurements for different substrate types, with no user involvement needed.

While the bias among different types of substrates can be intrinsically compensated, there will still be variations within a particular substrate type, e.g. wood. Through even more testing, the Analyzer has been shown to have an ultimate, estimated accuracy of 0.1 mg/ cm2 for wood and drywall, and an ultimate accuracy of 0.15 mg/cm2 for concrete and metal.

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XRF Analysis
Statistics

❖**Uncertainty definitions**

When taking measurements, the total uncertainty in the reading will be a combination of the precision and accuracy of the reading.

Remembering that precision is strongly impacted by the measurement length (time), the statistical uncertainty in the reading will continue to shrink as time progresses. At some point, the statistical variation will no longer dominate the total uncertainty and the accuracy, as stated above, will come to dominate. At this point, the measurement will have reached a ‘plateau’, for which no additional time will help to improve.

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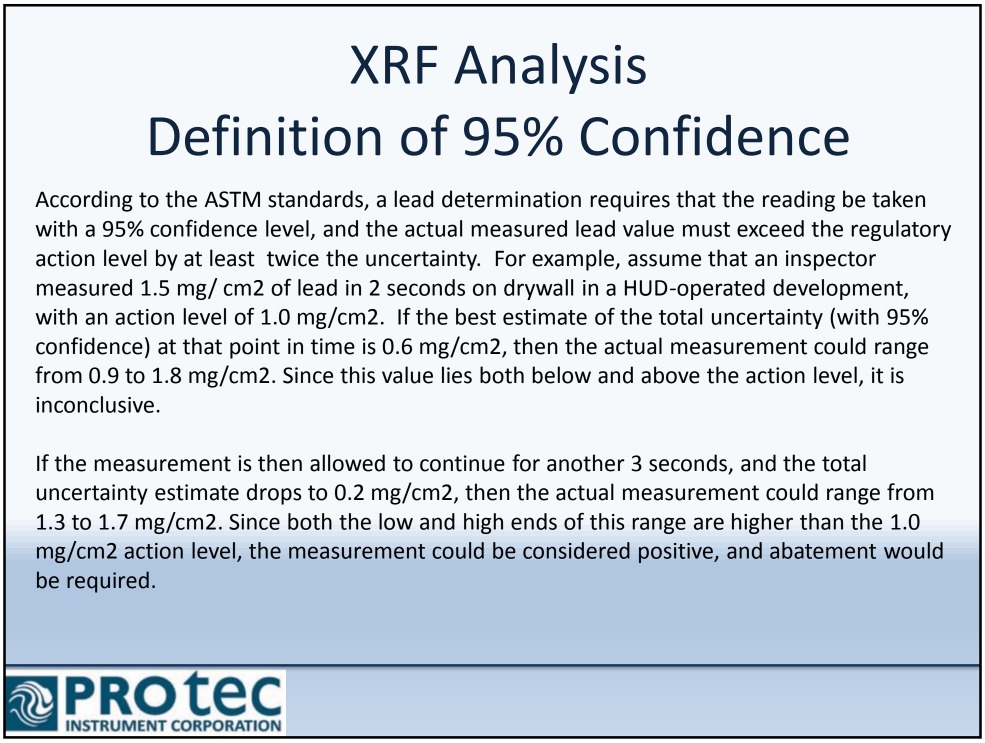
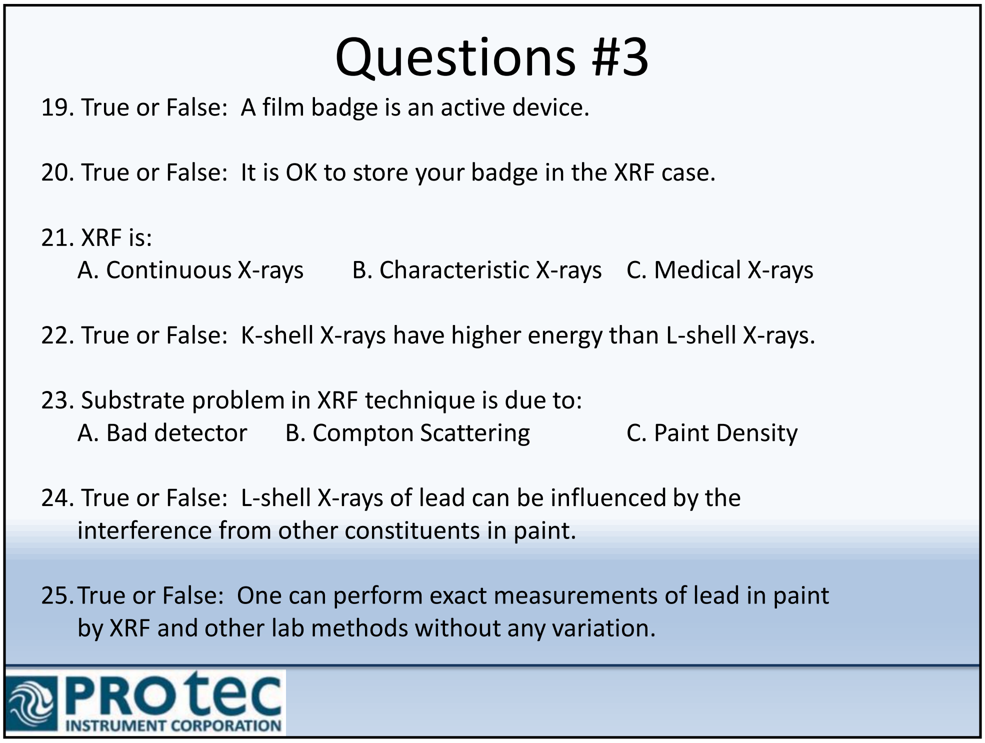


According to the ASTM standards, a lead determination requires that the reading be taken with a 95% confidence level, and the actual measured lead value must exceed the regulatory action level by at least twice the uncertainty. For example, assume that an inspector measured 1.5 mg/cm2 of lead in 2 seconds on drywall in a HUD-operated development, with an action level of 1.0 mg/cm2. If the best estimate of the total uncertainty (with 95% confidence) at that point is 0.6 mg/cm2, then the actual measurement could range from 0.9 to 1.8 mg/cm2. Since this value lies both below, and above, the action level, it is inconclusive.

If the measurement is then allowed to continue for another 3 seconds, and the total uncertainty estimate drops to 0.2 mg/cm2, then the actual measurement could range from 1.3 to 1.7 mg/cm2. Since both the low and high ends of this range are higher than the 1.0 mg/cm2 action level, the measurement could be considered positive, and abatement would be required.



19. True or False: A film badge is an active device.

20. True or False: It is OK to store your badge in the XRF case.

21. XRF is:
A. Continuous X-rays B. Characteristic X-rays C. Medical X-rays

22. True or False: K-shell X-rays have higher energy than L-shell X-rays.

23. Substrate problem in XRF technique is due to:
A. Bad detector B. Compton Scattering C. Paint Density

24. True or False: L-shell X-rays of lead can be influenced by the interference from other constituents in paint.

25.True or False: One can perform exact measurements of lead in paint by XRF and other lab methods without any variation.

Licensing requirements Licensing

Federal: NRC (Nuclear Regulatory Commission), control of byproducts.

State: Agreement states, non-agreement states, control of NARM, CRCPD.

Co-57 is a NARM source controlled by states, although some states have given control to the NRC for distribution under either General or Specific License.

PROtec INSTRUMENT CORPORATION

To possess radioactive material in the United States, In most States it requires the acquisition of some kind of license or registration.

To understand what type of license you are required to have, between either federal or the state, the type of radioactive source you are using is required. Cobalt 57 is a NARM source, or naturally occurring accelerator produced. In this case, the accelerator produced NARM sources are regulated by the individual states, unless the State has given jurisdiction to the NRC. (Nuclear Regulatory Commission)

Licensing requirements
Specific or General License

Specific License – State or NRC

- Requires that the user or company complete an application.
- Application or registration fee required.
- 30-60 day processing time

General License – NRC

- Agreement States
- Typically does not require application.
- PROTEC is responsible for notifying the State.
- XRF can only be used within State boundaries

PROTEC INSTRUMENT CORPORATION

NARM sources governed by the individual states are either covered by a specific license or a general license. For a manufacturer to ship a device that contains a NARM source, such as an XRF instrument, the device must be reviewed to ensure that it meets certain standards. At the conclusion of the review, the device is issued a safety evaluation registry number. Some states accept the General license concept, which means that the distribution of the device can be done without the individual going through the same application process required for the specific license, having nothing to do with the type of source or equipment. The major difference between a generally licensed device and a specifically licensed device is that, under the general license, the device can only be operated within that state. Typically you can only gain reciprocity through a specific license, or if your device is shipped under the General License. If you would like to use the device in a neighboring state that only accepts a Specific license, you must obtain a specific license in that state. If there is any question as to whether or not your state accepts the General or Specific license, please contact the individual state's regulatory agency, the NRC or PROTEC.

Radioactive Material Licensing

Requirements for obtaining a Specific License

The typical state radioactive material license application requires:

- Isotope information
- Radiation safety program to address:
  - Safe keeping of the device
  - Maintaining the labels in good condition
  - Leak testing of the device
  - Transportation of the device
  - Maintaining records and paperwork
  - ALARA concept at work
- Accidental reports
- Personnel monitoring
- Waste disposal
- Training

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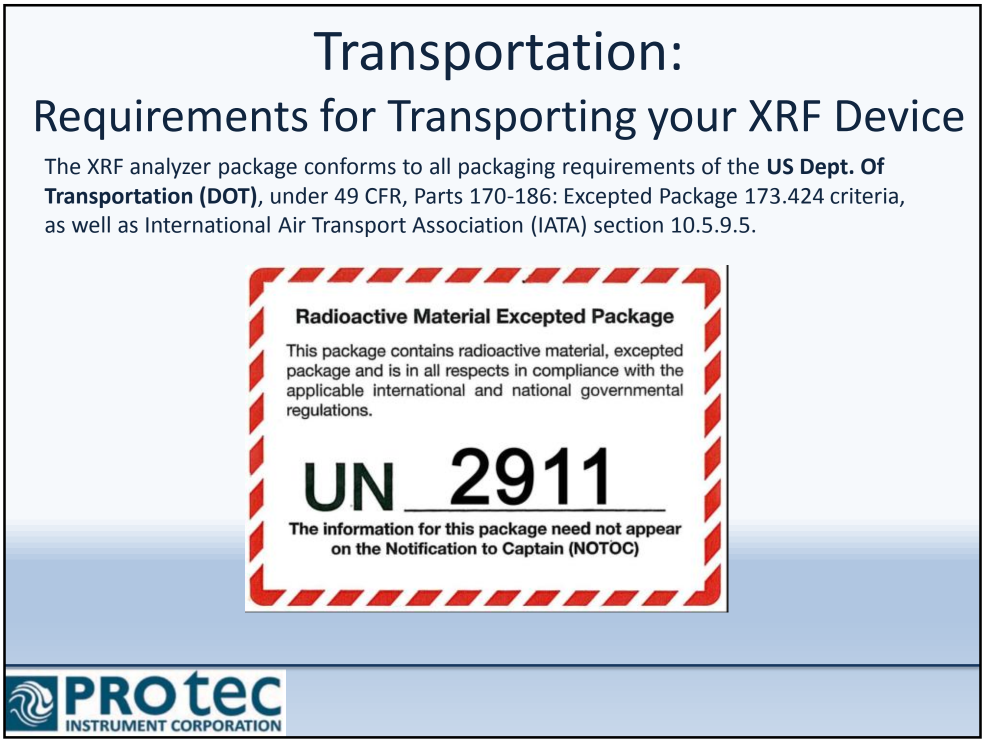
The application process for obtaining a specific license requires that you describe your radiation safety program, how the device will be stored, your leak testing procedures, what type of records your company will keep, what type of personnel monitoring you will use, the type of training you have had with this device, your plan for waste disposal, etc.



Any material that's classified or categorized as hazardous material must follow DOT transportation codes. Radioactive material is a category 7, meaning that if you want to ship it, you have to follow certain procedures. XRF devices must always be transported in their carrying cases, because these have DOT traveling certification. We recommend that when you receive your system from PROTEC, that you maintain the box it was shipped in, as well as all of the paperwork that is included with the shipment. If you are shipping your device to PROTEC for source replacement or repair, it must be shipped in its case.

With regard to hazardous materials, the PROTEC XRF device falls under the exempt category. Therefore, on your FedEx shipping label, there is no need to mark the package as hazardous. The regulatory paperwork that is included in the shipment states which section of DOT rules and IATA rules we have followed, because radiation on the level of that box is below 0.5 the minimum allowed per hour.

The shipment of radioactive material, as it stands today, is governed by 49 CFR of the DOT rules and regulations. XRF machines are generally shipped under section 173.424, which is excepted package for the shipment of radioactive material. The excepted package category allows the operator to ship the device without having to complete a dangerous goods declaration or attach a radioactive material to the box or container. As long as the device is in it's case, the case is in a shipping box, and that box is properly labeled, it can be taken on an airplane as regularly checked luggage.

These sections are subject to eventually change, and they could be referenced under another section in the future, so it's important to have the correct section noted as it appears on the shipping documents. It is also important to carry that document with you at all times in the event that you are asked to show it to an authority, or if, for any reason, you have to cite the section number.

There is also a list of rules and regulations under IATA, the International Air Transport Association. Among them, XRF packages have to be marked on two sides with a UN2911 label, indicating the presence of radioactivity, as seen on this label.

Transportation:

Requirements for Transporting the XRF

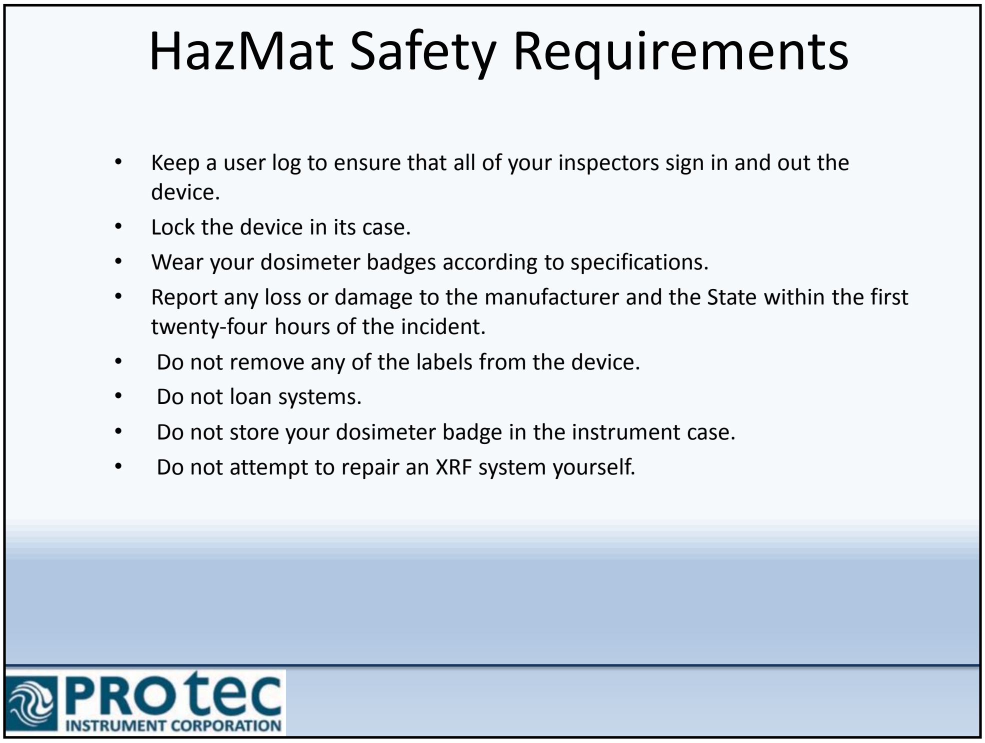
When traveling with an XRF device, the following pieces of information should be with your instrument:

- A Copy of your State/NRC License or Registration, **or** your General License information.
- Current Leak Test Certificate (required every 12 months)
- DOT Certification Document, which includes the emergency phone number
- Copy of your manufacturers radiation safety training certificate.
- The instruction manual.

PROtec INSTRUMENT CORPORATION

When traveling with an XRF device, you must have the following information in the XRF case:

- A Copy of your State/NRC License or Registration, or General license information.
- Current Leak Test Certificate (required every 12 months)
- DOT Certification document that includes the emergency phone number.
- A copy of your Manufacturers Radiation Safety training certificate.
- The instruction manual.



Please read the rules and regulations in the instruction manual that you will find with your LPA-1 device, and adhere to the following procedures:

- Keep a user log to ensure that all of your inspectors sign the device in and out.
- Lock the device in its storage case.
- Wear your dosimeter badges accordingly.
- Report any loss or damage to the manufacturer and to the State within the first twenty-four hours of the incident.
- Do not remove any of the labels from the device.
- Do not loan systems.
- Do not store your dosimeter badge in the instrument case.
- Do not attempt to repair an XRF system yourself.

If anything happens to the device where it cannot be repaired through our remote repair service, please contact PROTEC directly for a return authorization number, so the system can be returned to the manufacturer for servicing.

Questions #4

26. True or False: It is OK to loan the XRF to a person who is not licensed.
27. True or false: It is OK to sell your XRF to a person who does not possess a license.
28. True or False: Obtaining a radioactive source, or a device containing one, requires a license or a registration in most states.
29. True or False: It is OK to transfer a device containing a radioactive material across state lines without reciprocity license.
30. True or False: Radiation regulations are published in 10CFR20.
26. True or False: Transportation of radioactive materials in the US is regulated under 49CFR.
27. True or False: Radioactive materials are considered Category 7 hazardous materials.
28. Packaging category of a package containing a radioactive material is a function of:
    A. The source activity and measured dose at the surface of the package
    B. State regulations
    C. The labels used for the package
    D. Dangerous goods declaration

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Thank you!

You have now completed your radiation safety training and are ready to use your PROTEC Instrument Corporation LPA-1 XRF Lead Paint Analyzer!