Applications of Nuclear Science & Technology

From Education to Industry and Power to Medicine

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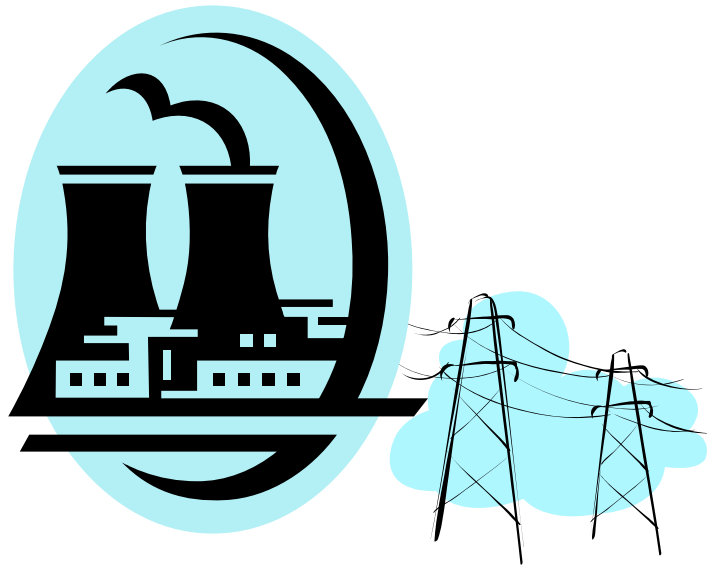
American Nuclear Society
OSU Student Chapter

Overview

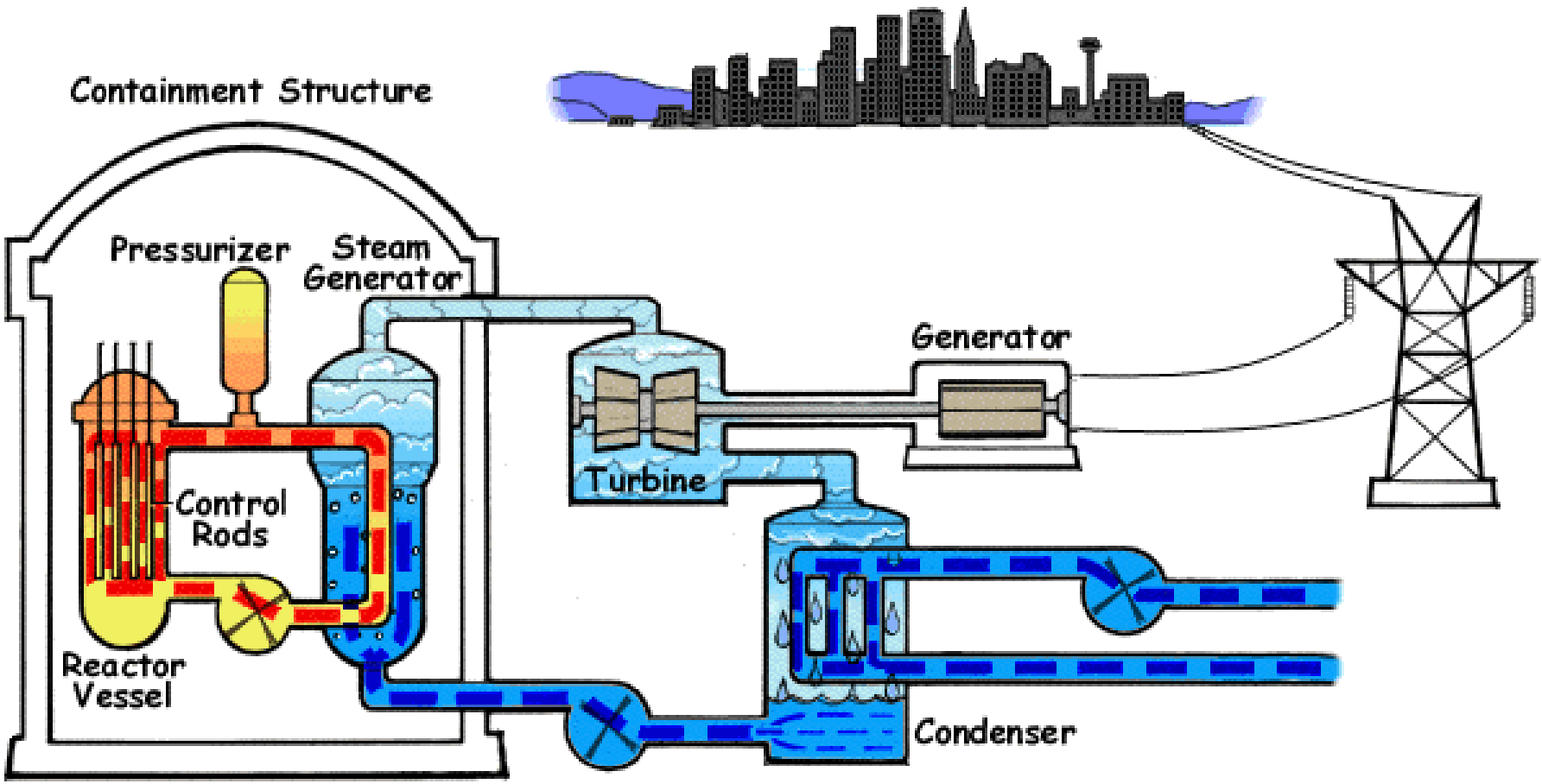
- Power Generation
- Medicine
- Nuclear Research in Cancer Therapy
- Food and Agriculture
- Scientific Research and Industry
- Public Safety and Crime Fighting

Nuclear Power Plants

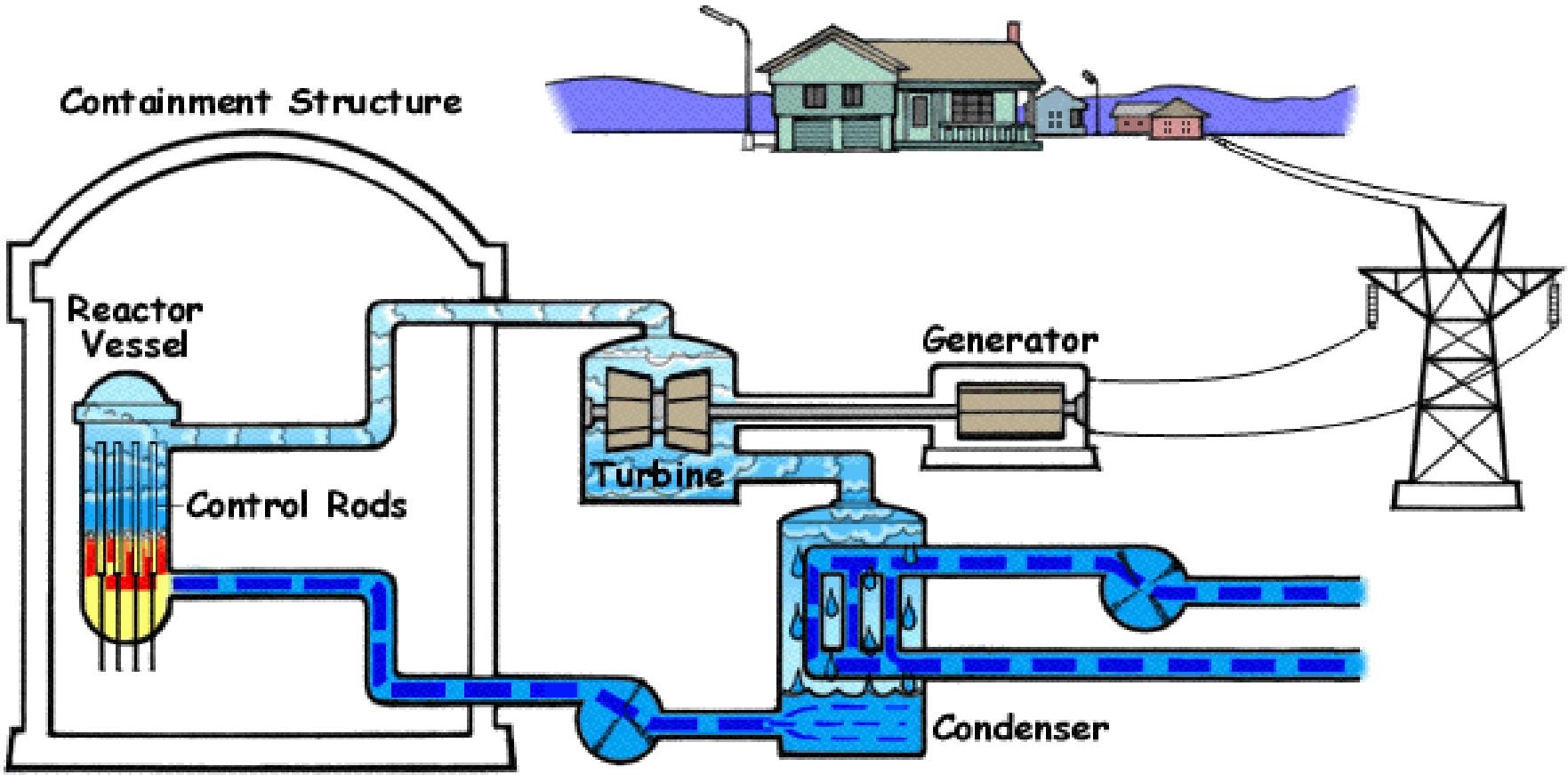
- 104 operating nuclear power plants in the U.S.
  - 20% electricity
- Uses controlled nuclear fission
- Light Water Reactor (LWR)
  - Pressurized Water Reactor (PWR)
  - Boiling Water Reactor (BWR)



Pressurized Water Reactor



Boiling Water Reactor



Medicine

- **Sterilization of Medical Products**
- **New Drug Research**
- **Diagnosis**
  - Tracers
  - Medical Imaging
- **Cancer Therapy**

Nuclear Research in Cancer Therapy

- **Boron neutron capture therapy**
  - Recent advances in killing malignant brain tumors (extensive work at Ohio State)

- **Cell directed radiation therapy**
  - Direct injection into tumors
  - Hyperactive Thyroid and Graves Disease control (I-131)

Agriculture

- Reduce Needs for Fertilizers and Water
- Speed Breeding of Improved Crops
  - Greater yields
  - Better nutritional value
  - Increased disease resistance for development
- Animal Husbandry
  - Increase body weight
  - Vaccines to eliminate diseases
- Insect Control

Co-60 food irradiator

Food Irradiation

- Kill pathogens and insects
- Extends shelf life
- Contamination Detection
- Examples:
  - Strawberries, tomatoes, onions, oranges, grapefruit
  - Poultry and eggs
  - Dried spices and seasonings
- Irradiated food is NOT radioactive!!

Industry

- Mineral and Resource Prospecting
  - Oil-well logging (rock formation characteristics)
  - Water supplies (aquifer interconnections)
  - Mineral deposits
- Non-destructive testing
  - Weld inspection
  - Thickness gauging
  - Pressure vessel inspection

Scientific Research

- Dating of Artifacts
- Tracers
  - Movements of materials along riverbeds or seashores
- Environmental Protection
  - Air, water and soil pollution/contamination
  - Global Climate Change
- Space Exploration

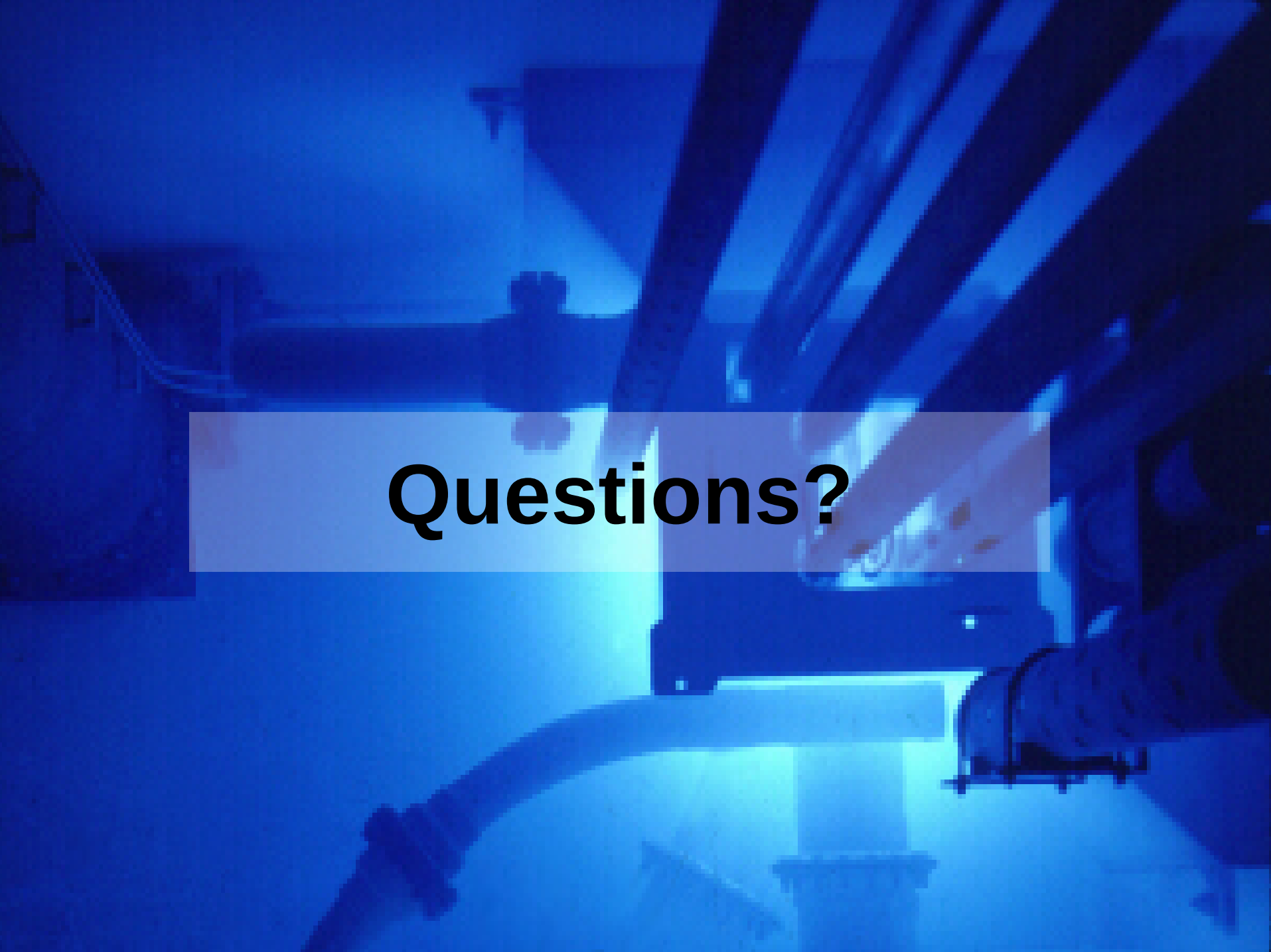
Public Safety and Crime Fighting

- Fighting terrorism
- Lighting (airports, exit signs, traffic control)
- Homes (smoke detectors)
- Neutron Activation Analysis
- Gun Powder Residue Analysis
- DNA Fingerprinting
- Art Counterfeiting

Californium based explosion detection system

Review

- There are many uses for nuclear science and technology in our world other than making power.
- We use them in our daily lives probably without even realizing it.
- Without these technologies, our lives would be much more difficult.


Questions?

Radiation Basics
&
Radiation in the Environment

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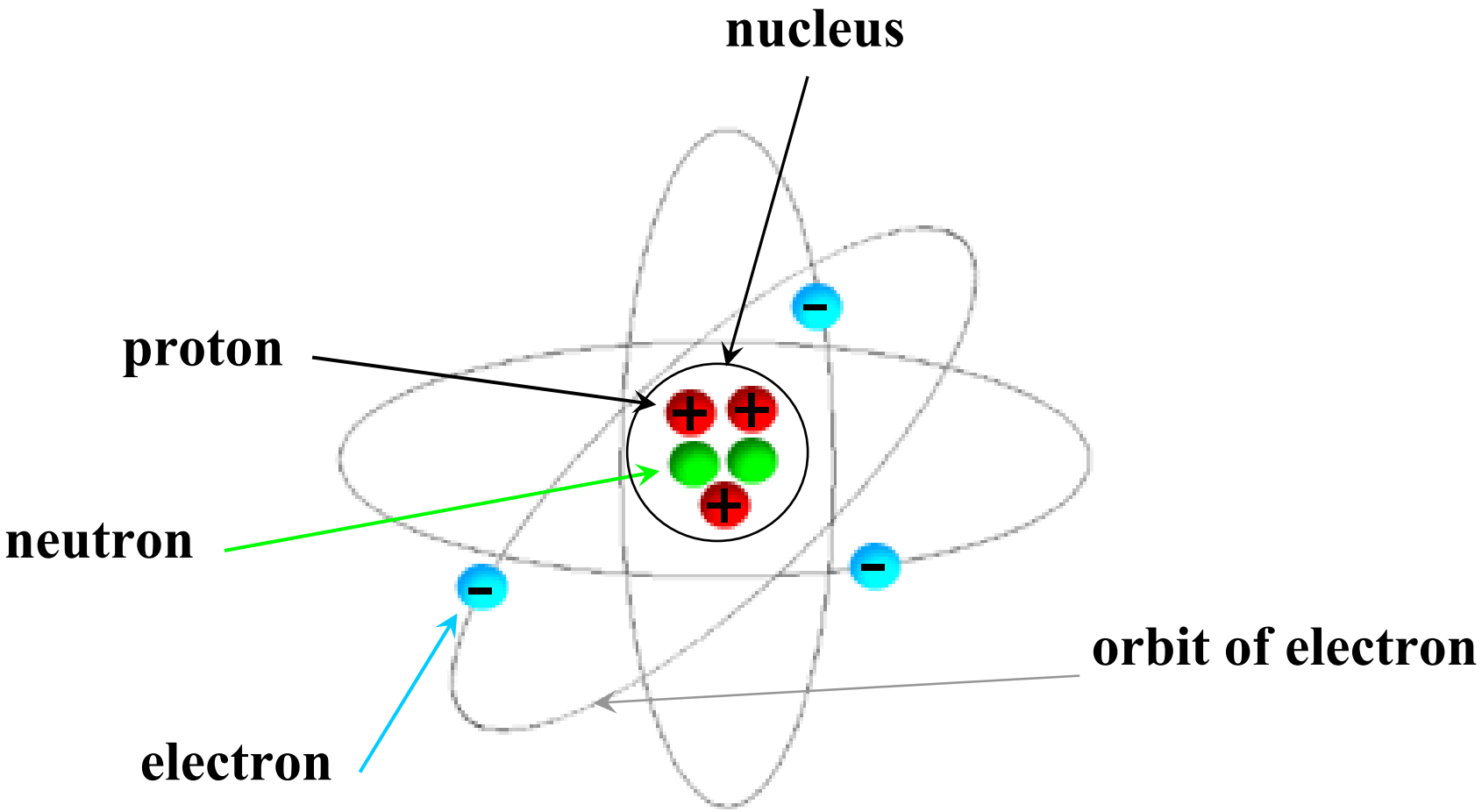
Overview

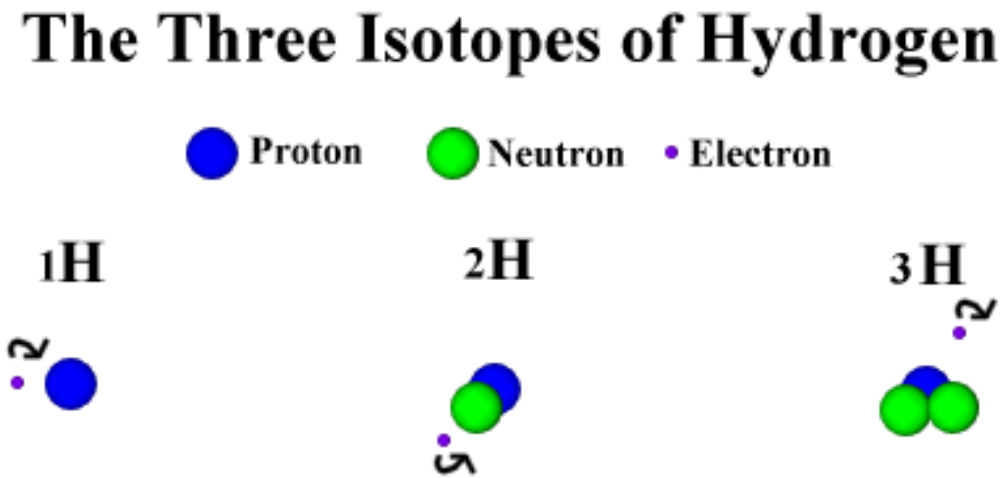
- Atom
- Isotopes
- Unstable Atoms
- Radioactivity
- Basic Types of Decay
- Units
- Half-Life
- Decay Curves

An Atom



Isotopes

- **Isotope**: Nuclide with the same proton number but different neutron number



Uranium Isotopes

$$\underbrace{{}^{234}_{92}U}_{A=234,\ Z=92,\ n=142},\quad \underbrace{{}^{235}_{92}U}_{A=235,\ Z=92,\ n=143},\quad \underbrace{{}^{238}_{92}U}_{A=238,\ Z=92,\ n=146}$$

Total of 22 isotopes of Uranium

Unstable Atoms

- Some nuclei are unstable
  - Caused by ratio of neutrons to protons
  - Atom with unstable nucleus is radioactive
  - Nucleus needs to emit a particle and/or energy to become stable
  - Release of this particle and/or energy is called a Decay

Three Common Decay Modes

- Alpha Radiation
  - 2 neutrons and 2 protons leave the nucleus
  - Alpha particle also leaves with an energy characteristic to the isotope
- Beta Radiation
  - An electron is emitted by the nucleus with a characteristic energy
- Gamma Radiation
  - An energetic photon is emitted by the nucleus with a characteristic energy

Radioactive Decay

- Particles and/or energy is released from a radioactive (unstable) atom resulting in a more stable atom
- Multiple decays may be required to reach a stable atom
- Alpha and Beta decays are usually accompanied by a simultaneous Gamma emission
- The original radioactive atom is called the ‘parent’ and the atom after the decay is called the ‘daughter’

Rate of Decay

- The rate of radioactive decay is unique to each radioactive isotope
- Radioactive decay is random and uncontrollable
  - Heating, cooling, chemical reactions, etc. do not change the decay rate
  - Decay rate can be used to identify an isotope
- Because the decay process is random, it can be analyzed statistically

Units of Radioactivity

- Curie
  - Traditional unit of activity
  - 1 Ci = 3.7×10^{10} decay per second
  - Based on the decay rate of 1 gram of Radium-226
- Becquerel (Bq)
  - SI Unit
  - 1 Bq = 1 decay per second

Half-life

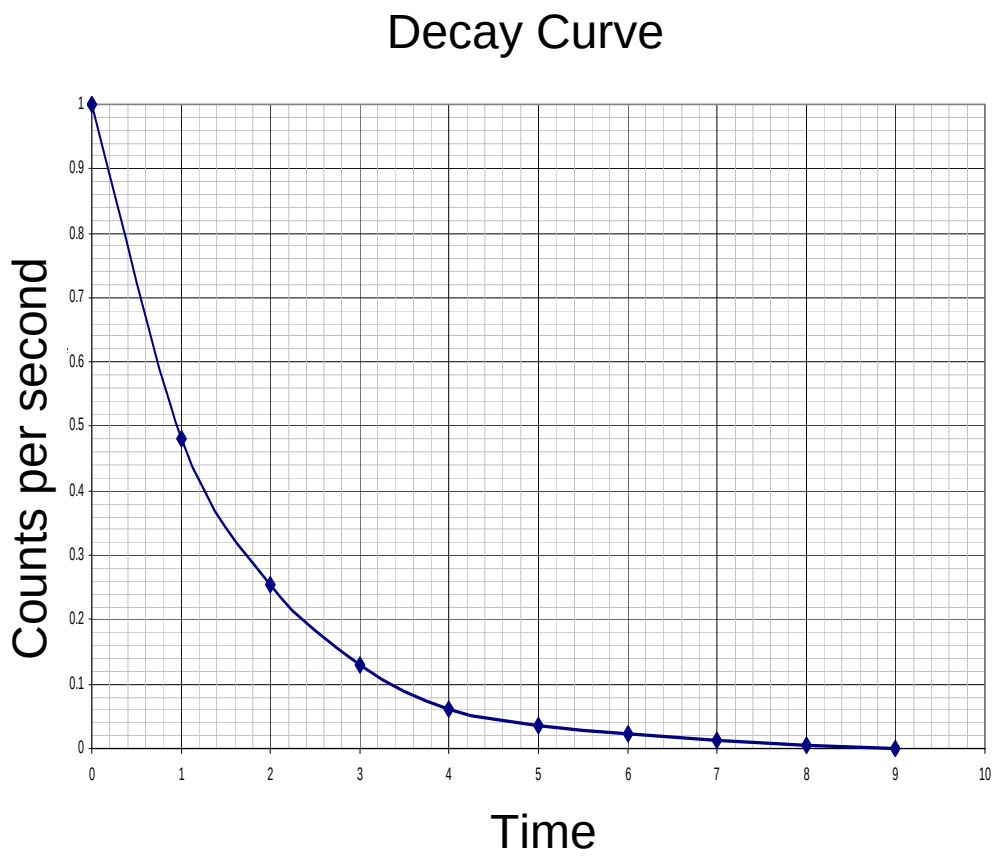
- **Half life**: the length of time required for a radioactive material to decay ½ of its initial number of radioactive atoms
- Half lives are characteristic to each isotope
  - millionths of a second for highly radioactive fission products
  - to billions of years for long-lived materials (such as naturally occurring uranium).
- Less than 1% of the initial activity remains after 7 half lives have passed
- Activity of a source is dependant on the number of radioactive atoms and the half life of the particular isotope

Half-lives of Selected Isotopes

Nuclide	Half-life, $T_{½}$	Radiation Emitted
Uranium-238	4.51×10^9 years	α, γ
Potassium-40	1.28×10^9 years	β, γ
Radium-226	1 599 years	α, γ
Radon-222	3.82 days	α, γ
Thorium-219	1.05×10^{-6} s	α

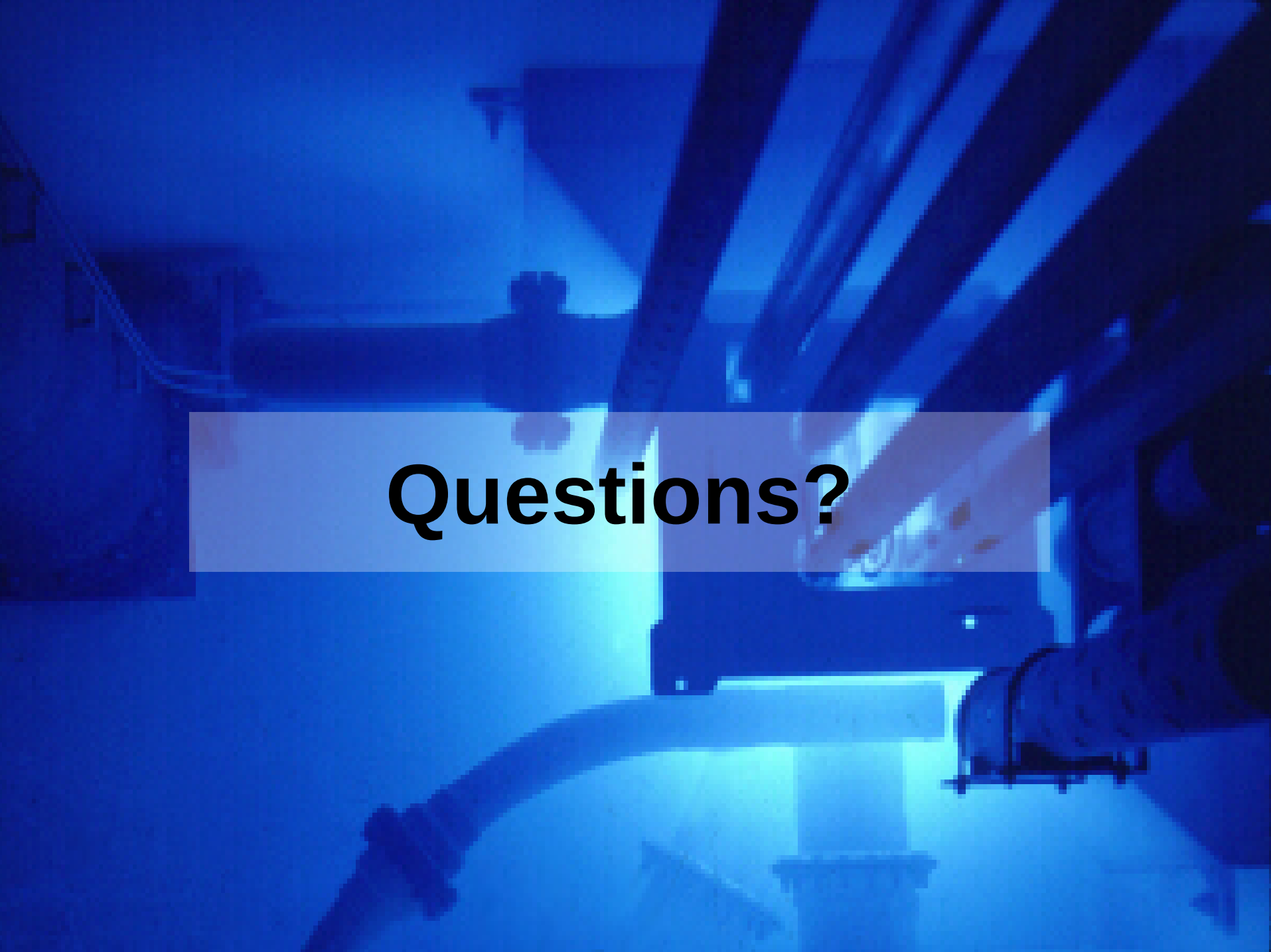
Radioactive Decay Curves

- Exponential Decay
- In reality, never reaches 0.
- There will always be radioactive atoms left.
- Random but predictable process.



Review

- Radiation - particles or energy emitted from an unstable nucleus to make an atom stable.
- Three major types of radioactive decay: alpha, beta, and gamma.
- Radioactive atoms decay with time predictably by an exponential function.


Questions?

Radiation All Around Us

Sources of Naturally Occurring and Man-made Radiation

Activity: Calculate Your Background Dose

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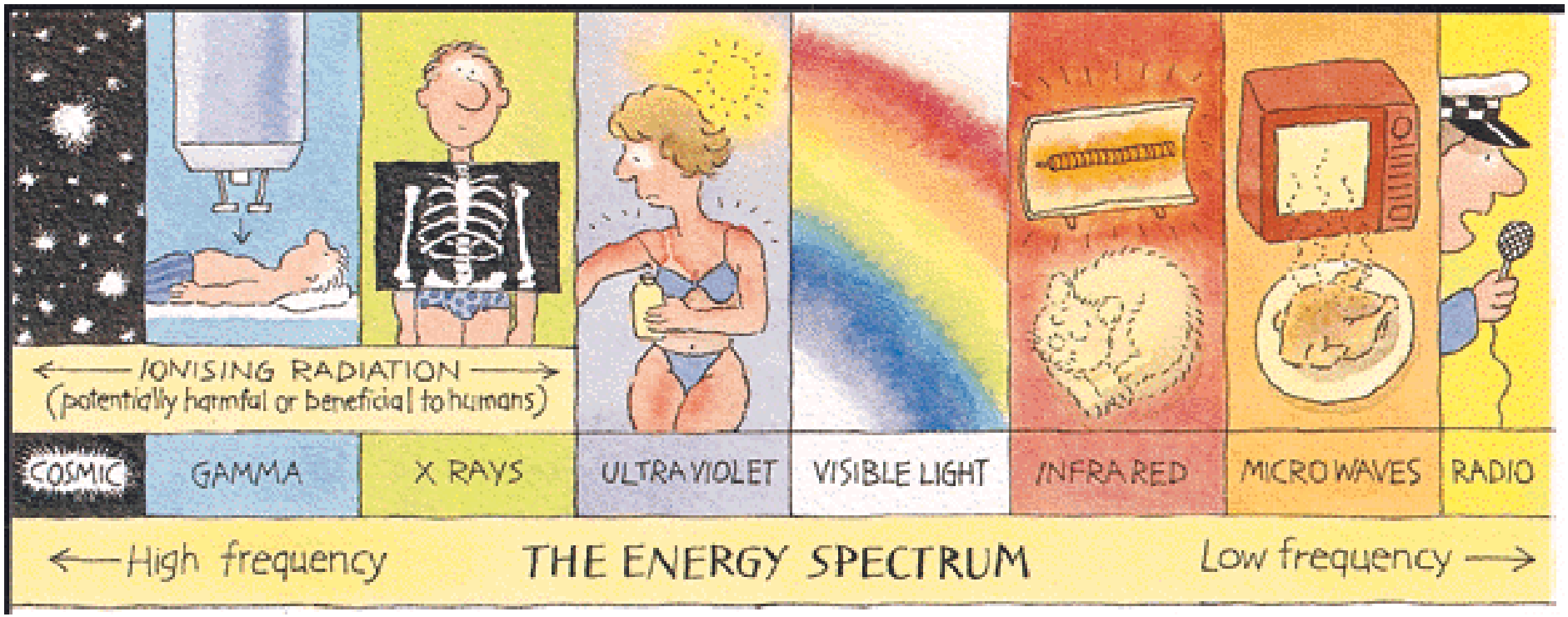
Overview

- Types of naturally Occurring Radiation
- Sources of Radiation
  - Natural
  - Man-made

Background Radiation

- Natural + Man-Made

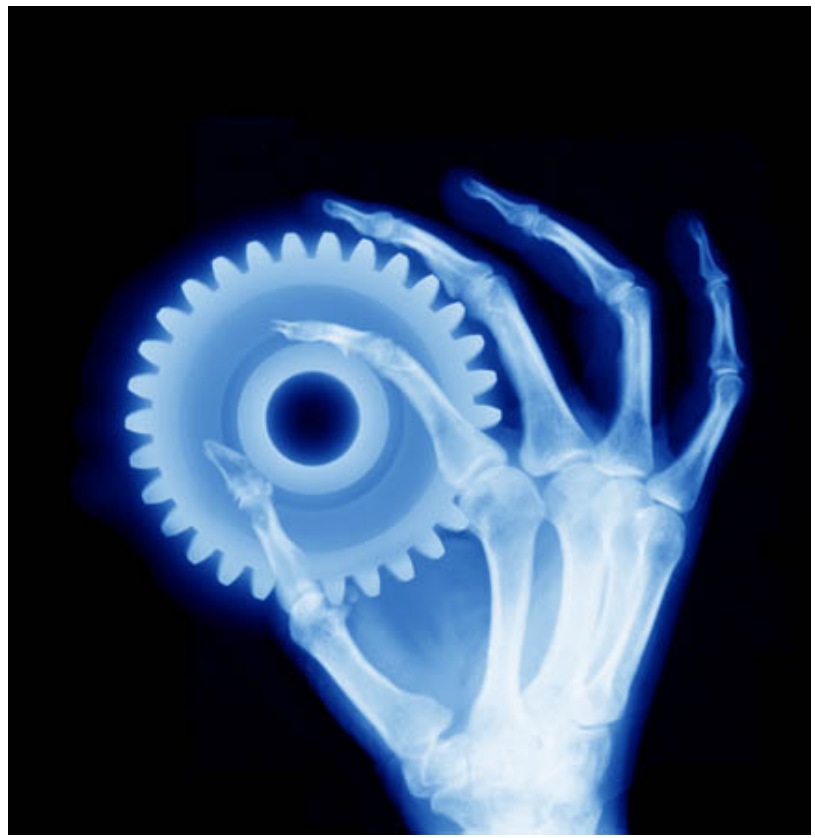


Sources of Radiation: Natural

- Cosmic:
  - Sun
- Terrestrial: sources in the earth's crust
  - Soil (radon)
  - Water
  - Vegetation (Bananas)
- Internal: sources in the human body
  - Potassium-40
  - Carbon-14
  - Lead-210

Sources of Radiation: Man-made

- Medical
  - X-rays
  - Cancer treatments
- Commercial
  - TV
  - Lantern mantels
  - Smoke detectors
  - Fuel cycle
- Industrial
  - Well logging
  - Non-destructive testing



Varying Background Dose

- Background dose varies by location
  - Ohio background dose is higher due to shale deposits
  - Denver background dose is higher due to elevation
  - Patients undergoing extensive radiation will receive higher doses
  - Frequent fliers and miners receive higher doses

Summary

- Natural sources of radiation
  - Cosmic
  - Terrestrial
  - Internal
- Man-made sources of radiation
  - Medical
  - Commercial
  - Industrial

Activity: Determining Your Personal Annual Radiation Dose

Average Annual Dose of Ionizing Radiation

- All living creatures constantly receive a certain amount of radiation from outer space, the soil, food we ingest or even the air we breathe. The sources of radiation fall under two categories: natural and man-made, collectively known as **background radiation**. The average annual personal dose from background radiation is approximately 350 mRem/year. In the United States, radon gas contributes to over half of this dose, and about 11% is from irradiation from inside our bodies.

What You Are To Do

- In this activity, you will estimate your personal annual radiation dose using the Background Information Worksheet provided. You will then compare your results with those of other groups. When doing this activity, keep in mind that the amount of
  - terrestrial radiation varies in different parts of the world due to different concentrations of uranium and thorium in soil.
  - cosmic radiation varies in different parts of the world due to differences in elevation and to the effects of the earth's magnetic field.

Materials

- Background Information Worksheet
- Pencil
- Calculator

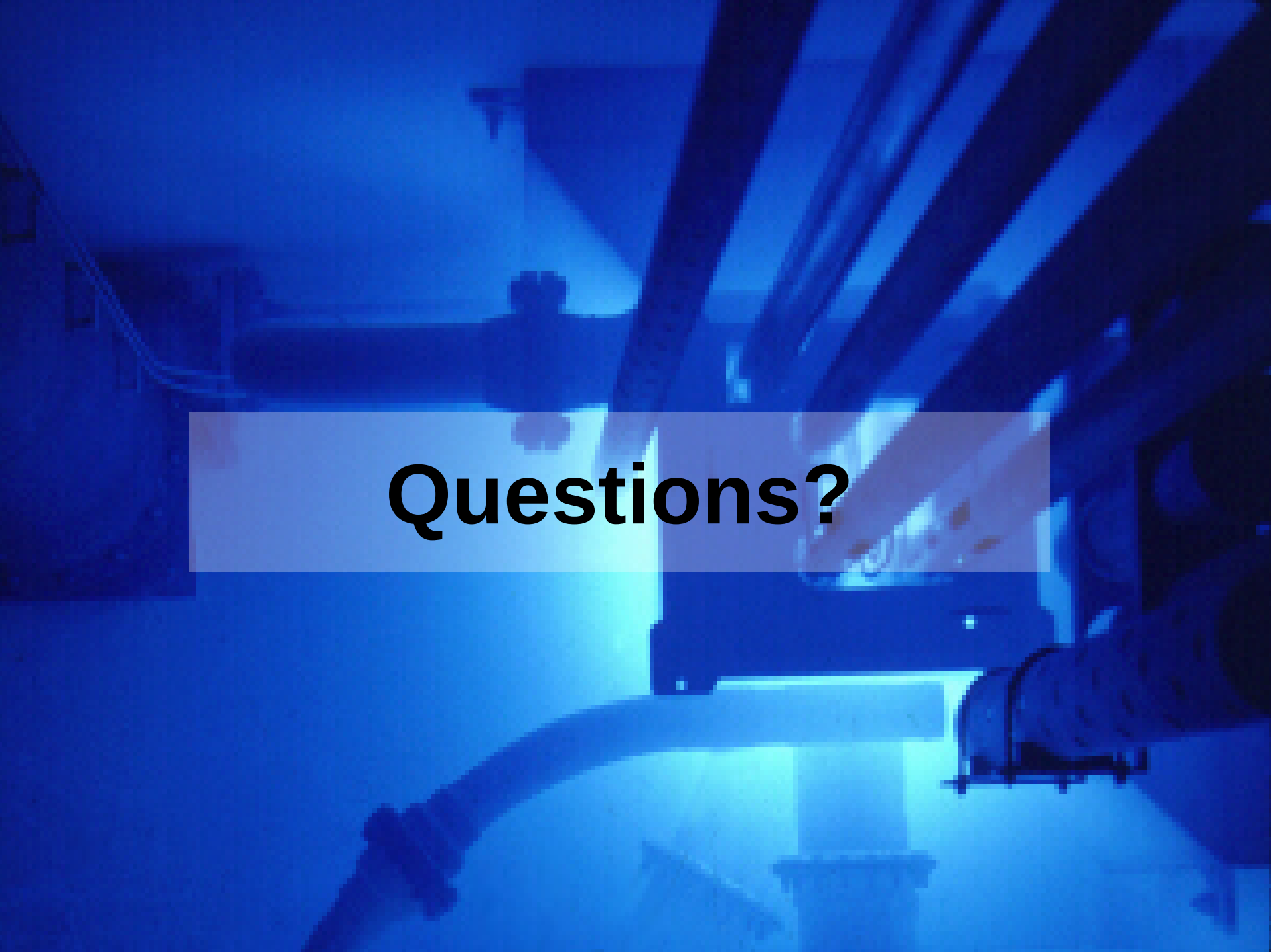
Primary Objectives

1. To make students aware how much radiation they have been exposed to.
2. To make the students aware of what types of things give them an exposure.
3. To compare their dose to a typical dose in other cities or received by people in other professions (airplane pilot).

Procedure

- Complete the worksheet and tally the total.
- For central Ohio, the average elevation is about 825 feet above sea level
  - approximate dose is 28 mRem/year from cosmic radiation.
- For every hour in an airplane, you receive 0.5 mRem
- Make sure to use 30 mRem/year for the second entry.
- In central Ohio, we are not within 50 miles of a power plant. However in southern Ohio, many coal plants along Ohio River.

FACTORS	COMMON SOURCES OF RADIATION	YOUR ANNUAL DOSE (mrem)
WHERE YOU LIVE	**Cosmic radiation** (from outer space) Exposure depends on your elevation (how much air is above you to block radiation). Amounts are listed in mrem (per year). At sea level.....26 mrem; 0 - 1000 ft.....28; 1-2000 ft.....31; 2-3000 ft.....35 mrem; 3-4000 ft.....41; 4-5000 ft.....47; 5-6000 ft.....52; 6-7000 ft.....66 mrem; 7-8000 ft.....79; 8-9000 ft.....96 [Elevation of cities (in feet): Atlanta 1050; Chicago 595; Dallas 435; Denver 5280; Las Vegas 2000; Minneapolis 815; Pittsburgh 1200; St. Louis 455; Salt Lake City 4400; Spokane 1890.]	28 mrem
	Terrestrial (from the ground) If you live in a state that borders the Gulf or Atlantic Coasts, add 16 mrem If you live in the Colorado Plateau area (around Denver), add 63 mrem If you live anywhere else in the continental US, add 30 mrem.	30 mrem
	House Construction If you live in a stone, adobe, brick or concrete building, add 7 mrem	7 mrem
	Power Plants If you live within 50 miles of a nuclear power plant, add 0.01 mrem If you live within 50 miles of a coal-fired power plant, add 0.03 mrem	0 mrem
FOOD WATER AIR	**Internal Radiation***** From food (Carbon-14 and Potassium-40) & from water (radon dissolved in water) From air (radon)	40 mrem 200 mrem
HOW YOU LIVE	Weapons test fallout (less than 1)* .....1 mrem	1 mrem
	Jet Plane Travel .....0.5 mrem per hour in the air	17 mrem
	If you have porcelain crowns or false teeth** .....0.07 mrem	mrem
	If you wear a luminous wristwatch .....0.06 mrem	mrem
	If you go through luggage inspection at airport .....0.002 mrem	0.002 mrem
	If you watch TV* .....1 mrem	mrem
	If you use video display terminal (computer screen)* .....1 mrem	1 mrem
	If you have a smoke detector .....0.008 mrem	0.008 mrem
	If you use a gas camping lantern .....0.2 mrem	mrem
	If you wear a plutonium-powered pacemaker .....100 mrem	mrem
MEDICAL TESTS	**Medical Diagnostic Tests** – Number of *millirems per procedure* X-Rays: Extremity (arm, hand, foot, or leg).....1 Dental.....1 Chest.....6 Pelvis/hip .....65 Skull/neck.....20 Barium enema.....405 Upper GI.....245 CAT Scan (head and body).....110 Nuclear Medicine (e.g., thyroid scan).....14	0 mrem
	YOUR ESTIMATED ANNUAL RADIATION DOSE	324.01 mrem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